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A Guide to the Common Phytoplankton of the St. Croix Estuary, New Brunswick

David J. Rawlence,

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THE NEW BRUNSWICK MUSEUM

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A GUIDE TO THE COMMON PHYTOPLANKTON OF THE ST. CROIX ESTUARY, NEW BRUNSWICK

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1987

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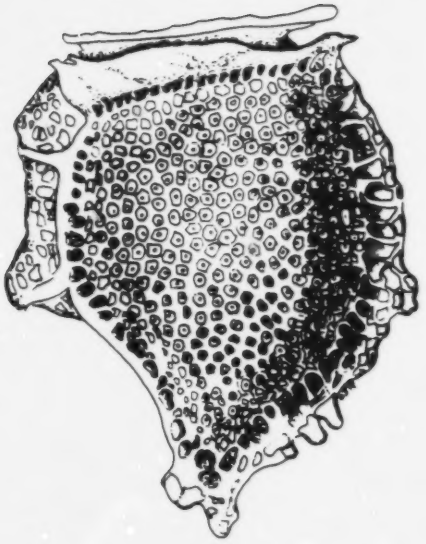

Dinophysis norvegica Clap. and Lachmann

ABSTRACT

The St. Croix is one of three rivers discharging into the Bay of Fundy through Passamaquoddy Bay, which supports the most productive fishery in the Bay of Fundy. Mean tidal amplitude at the head of the Estuary is 6.1 m, which, combined with the considerable discharge from the St. Croix, contributes to the generally high suspended load characteristic of the estuary. The spring and autumn phytoplankton maxima are therefore restricted vertically by rapid light attenuation, and distributed horizontally in somewhat patchy fashion.

The three major groups of phytoplankton are covered in this guide; diatoms, the loricate chrysophytes of the genus Dinobryon, and the dinoflagellates. Keys are provided for the identification of 108 diatoms, 7 species of Dinobryon, and 8 dinoflagellate taxa. Comments are included about the collection of phytoplankton, together with some guidance on the cleaning and preservation of diatoms.

RESUME

La Sainte-Croix est une des trois rivières qui se déversent dans la baie de Fundy en passant par la baie Passamaquoddy qui soutient l'activité de pêche la plus productive dans la baie de Fundy. L'amplitude moyenne des marées à l'embouchure de l'estuaire est de 6.1 m, qui, combinée avec un déversement considérable de la rivière Sainte-Croix, contribue à la charge en suspension élevée de l'estuaire. Le maximum de phytoplankton en automne et au printemps est donc limité verticalement par l'atténuation rapide de la lumière et réparti horizontalement de façon quelque peu inégale.

Les trois principaux groupes de phytoplankton sont abordés dans ce guide - Diatomées, chrysophysées du genre Dinobryon et dinoflagellées. Le guide contient également des observations sur la collection de phytoplankton ainsi que quelques conseils sur le nettoyage et la préservation des diatomées.

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ACKNOWLEDGEMENTS

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INTRODUCTION

The St. Croix River, along with the Magaguadavic and Digdeguash Rivers, flows into Passamaquoddy Bay, which in turn is connected to the Bay of Fundy through Letite, Western and Head Harbour Passages (Fig.1). The St. Croix River provides more than half the freshwater input into Passamaquoddy Bay, and part of its course constitutes the boundary between Canada and the United States. The Quoddy Region, encompassing Passamaquoddy Bay, the Deer Island Archipelago, Campobello Island, the Wolves and coastal waters from Point Lepreau to West Quoddy Head, supports the most productive fishery in the Bay of Fundy. The basis for the productivity is the considerable freshwater discharge, cold salt water and strong tidal mixing.

Because of its influence on the Quoddy Region, the biology and chemistry of the St. Croix Estuary is of particular importance. The natural and historical significance of the St. Croix has been further emphasised by its recent nomination for consideration as a Canadian Heritage River.

The Quoddy Region has been the focus of a considerable amount of scientific research over recent years, much of which is reviewed in Thomas (1983). The establishment of the biological station at St. Andrews, and later the Huntsman Marine Laboratory, provided considerable stimulus and some focus to research in the region. Various energy projects (Passamaquoddy Tidal Power Study, 1930 - 1969, Point Lepreau Nuclear project, Coleson Cove thermal station, Eastport Maine refinery) created additional research needs for the Quoddy and adjacent areas. The results of studies centered at the marine laboratories, together with those derived from the various energy projects, constitute a growing body of data for the region. However, a comprehensive body of information is not available for all components of the Quoddy regional biota.

While various studies have included some coverage of the phytoplankton of the St. Croix Estuary (Fritz, 1921; McMurrich, 1917; Lakshminaryana, 1983) most have been concerned principally with Passamaquody Bay (Davidson, 1934; Linkletter et al., 1977; Davidson, 1932; Gran 1933 and Braarud, 1934). The results of some investigations in adjacent areas are also relevant to an understanding of the biology of the St. Croix Estuary (e.g. Bigelow, et al., 1940; Gran, 1933; Riley, 1947; Marshall, 1978).

The phytoplankton in the St. Croix Estuary is regularly sampled for various purposes. The seasonal occurrence of the species responsible for paralytic shellfish poisoning is monitored, while the composition and distribution of the plankton flora is investigated during the course of studies based each year at the Huntsman Marine Laboratory. In spite of this interest in the phytoplankton flora, and the years over which these studies have been pursued, no seasonal investigation of the Estuary has been published. In October 1982, the University of New Brunswick began a comprehensive investigation of the phytoplankton in the St. Croix Estuary. This guide to the phytoplankton represents one of the products of this investigation.

The taxonomic literature on the phytoplankton is vast and widely scattered. Several standard taxonomic works may be consulted for the identity of the many species (e.g. Hustedt, 1928 - 1966; Patrick and Reimer 1966, 1975; Schmidt, 1874). These, however, are daunting to the inexperienced investigator. The many investigations of the St. Croix-Quoddy regions have not resulted in the development of a workable key to the phytoplankton. The lists of species from Passamaquoddy Bay (Lakshminaryana, 1983) and coastal waters of the northeastern United States (Marshall, 1978), constitute perhaps the most relevant sources of information about the phytoplankton of the St. Croix Estuary. The present key was designed as a first attempt to overcome this considerable obstacle to investigations of one of the most important and fascinating groups of the regional biota.

USE OF THE KEYS

This guide should provide the means of identification of the more important elements of the phytoplankton in the St. Croix Estuary. The keys are not comprehensive, as they are based solely on an intensive study of samples collected over a 12 month period.

In some instances the identity of individual species could not be completely established, and these have naturally been omitted from the keys. In other cases, satisfactory identifications were considered impossible without providing comprehensive species descriptions for the reader, or providing electron micrographs to illustrate particular structures. Species requiring comprehensive literature support were also omitted. Nevertheless, the use of this guide should permit identification of more that 85% of the taxa in the estuary.

It is assumed that most investigators would not wish to go to elaborate lengths to identify an individual species. To this end, most steps in the keys are based on features discernable with the aid of good quality microscope equipped with phase-contrast optics. Occasionally, however, species cannot be identified easily by means of features visible in uncleaned samples. Instructions are therefore given in a subsequent section for the removal of the organic components of any phytoplankton collection. However, many of the keys are primarily designed for the identification of live plankton. Therefore identification should always be attempted in the first instance using freshly collected samples.

The principal aim of this guide is to provide an introduction to the more common phytoplankton found in the St. Croix Estuary, in a manner that does not require an in-depth knowledge of taxonomic terms and concepts. A conservative approach is therefore adopted to taxonomic terminology. The only terms used are those necessary for the accurate identification of the plankton treated herein. Descriptive, non-technical terms are used where possible, thus reducing the amount of effort required to identify a species, without compromising the accuracy

of the identification. The key is designed for the undergraduate university student, or the serious layman. If is not intended for use in critical studies, although it may prove a useful introduction to the more technical taxonomic literature.

The serious investigator may consult a variety of other texts and manuals, including the following; Cleve-Euler (1968), Hendey (1964), Hustedt (1928 - 1966, 1930, 1985), Patrick and Reimer (1966, 1975), Peragallo & Peragallo (1897 - 1908) Schmidt (1874 - 1944).

The St. Croix Estuary phytoplankton is predominantly composed of representatives of the Division Chrysophyta, Class Bacillariophyceae (diatoms) and Class Chrysophyceae "golden algae", and dinoflagellates (Division Pyrrhophyta, Class Dinophyceae).

Members of both Divisions contain chlorophyll a and c, carotenes and xanthophylls, and both lack chlorophyll b. On occasion representatives of other algal Divisions may also be encountered in the St. Croix estuary, eg. Chlorophyta or Euglenophyta. Because of their relatively minor representation in comparison with that of the Bacillariophyceae and Dinophyceae, emphasis is here placed on these two classes.

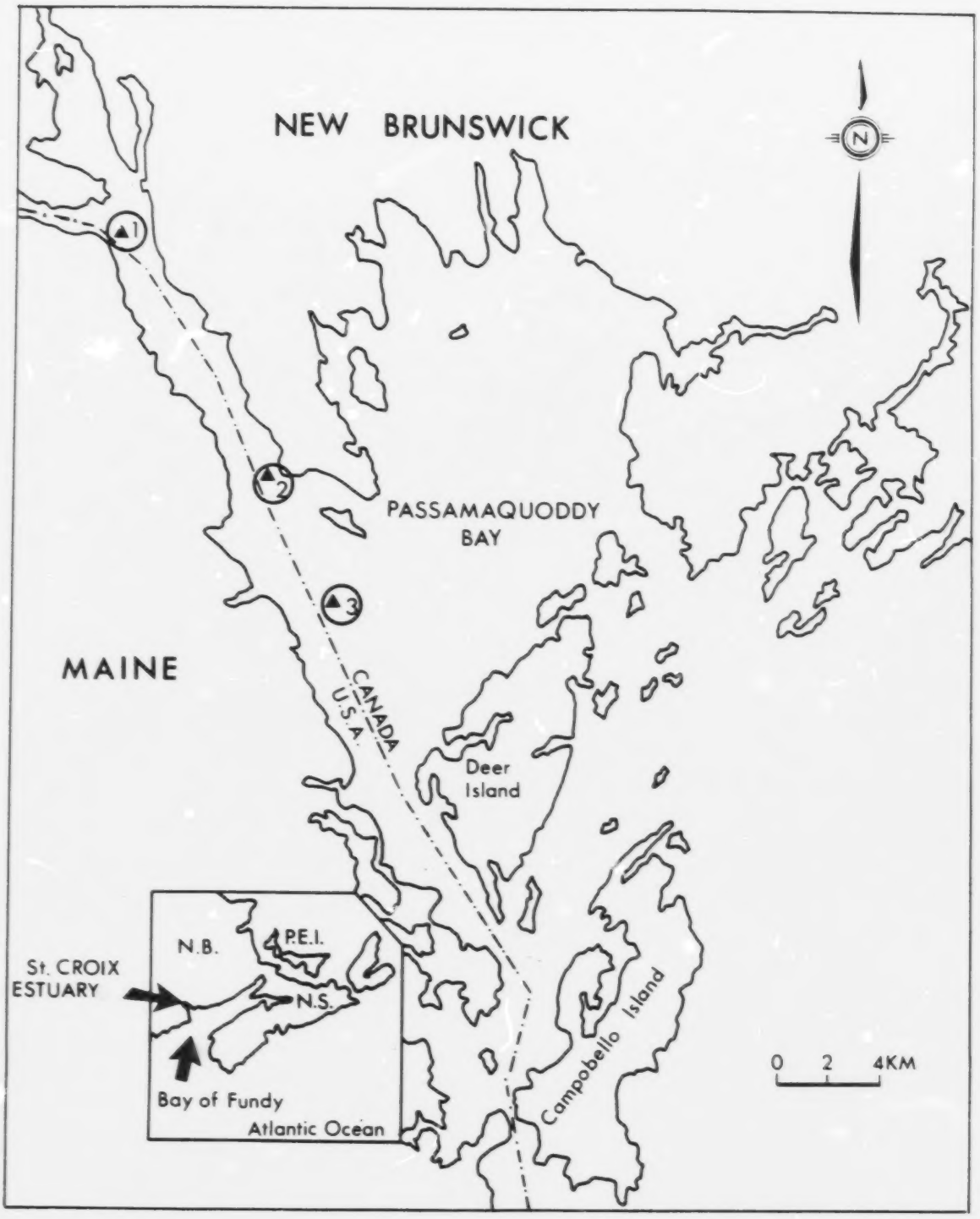


Figure 1. Passamoquoddy Bay and the St. Croix Estuary. The species described in this guide were collected at three sites (circles), two in the Estuary proper , and one in the southwest of Passamaquoddy Bay.

PRINCIPAL FEATURES OF THE DIATOM CELL (CHRYSOPHYTA, BACILLARIOPHYCEAE)

The diatom cell is enclosed within a protective shell or frustule largely composed of silica. Each frustule is composed of two halves which relate one to another in the manner of the two halves of a petri dish. These two pieces are termed epitheca and hypotheca, and their margins, which actually overlap to completely enclose the cell, are termed respectively the epi - and hypocingulum. The epi- and hypocingulum compose the girdle. In some species elongation of the cell is permitted by the addition of extra banks to the girdle, which thereby becomes a compound girdle or cingulum. The interrelationships of these structures are shown in Figure 2.

Two major types of frustule symmetry exist...radial and bilateral. The latter have valvar, apical and transapical planes of symmetry, while radially symmetrical frustules have pervalvar and valvar planes. The opposing surfaces of the valve wall may be referred to as the valve face, in chains of frustules these surfaces are seen from the side as valve ends. In many diatoms the valve face is variously ornamented, elevations are raised surfaces which do not project beyond the valve margin, while seta (setae) extend well beyond the valve margin, sometimes interlocking with those of adjacent valves to form chains. Extensions of the valve margins termed spines, may also join one valve to another. Hollow tubular strutted processes are formed on some valves. These provide points of egress for chitan threads which also join adjacent frustules. Strutted processes are normally visible in preparations viewed with a scanning electron microscope.

Many valves are prominently perforate with irregular holes or punctae, sometimes arranged in rows which appear as lines of striae. On occasion these walls are constructed after the fashion of a honeycomb, with inner and outer openings of different structure. The major elements of this type of wall pattern appear under the light microscope as areolae, in reality the space or locule between the inner and outer wall of the frustule. Valve areas devoid of such markings are termed hyaline fields. In some cases these regions are interrupted by a fissure or raphe, sometimes present in only one of a valve pair...the epivalve.

A discussion of reproduction is beyond the scope of this manual. However, it is necessary to refer briefly to aspects of growth and reproduction that relate to the classification of diatoms. In several groups it would appear although normal growth is accompanied by a gradual dimunition of the size of one of the daughter cells resulting form each division. There is, therfore, a considerable range in the size of frustules in some species. On occasion resting spores may be formed wholly or partly within the parent frustule, or completely outside it. The ornamentation of these structures is usually quite different from that of the parent. In some cases the structure of the two halves is different, but they typically consist of two valves without a girdle. The main elements of diatom structure are illustrated in Figure 2.

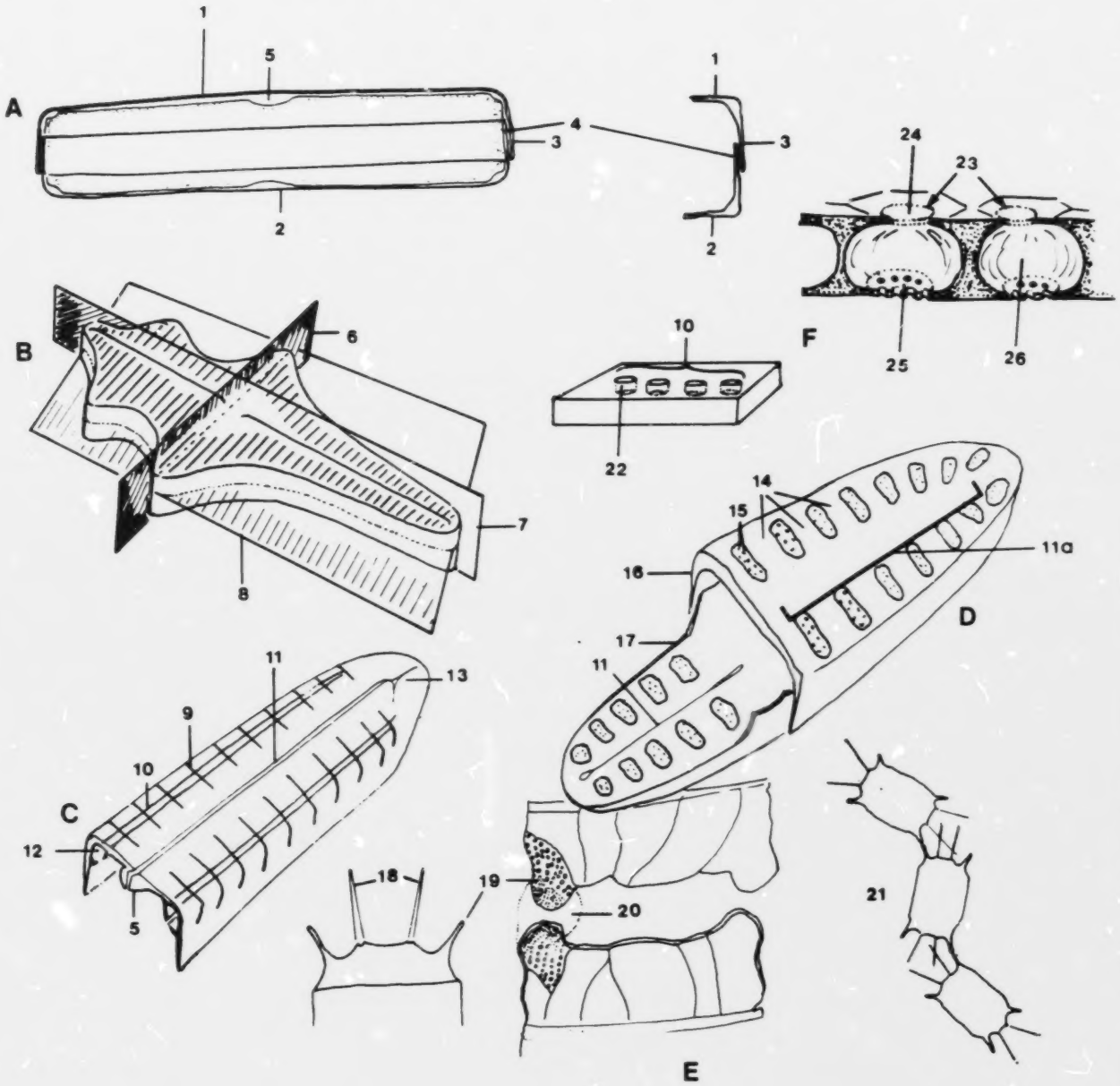


Figure 2. Details of diatom structure.

A. 1. epivalve 2. hypovalve 3. epicingulum 4. hypocingulum (girdle bands) 5. central nodule.

B. Planes of symmetry in naviculoid diatoms. 6. transapical 7. apical 8. valvar.

C. Features of Pinnularia-type frustule. 9. costae 10. striae 11. raphe 11a. pseudoraphe 12. chamber 13. polar nodule.

D. Parts of Achnanthes-type frustule. 14. costa 15. punctae 16. epivalve 17. hypovalve

E. Surface ornamentation. 18. setae 19. elevations 20. mucilage pad 21. chain of cells united by mucilage pads.

F. Details of wall structure. 22. puncta 23. areola, consisting of: 24. foramen 25. cribrum, and 26. locule

(C, D) After Bourrelly (1981).

PRINCIPAL FEATURES OF THE CHRYSOPHYCEAN CELL (CHRYSOPHYTA, CHRYSOPHYCEAE)

There is a great deal of variation in cell covering amongst members of this class. Some cells lack any protective covering while others produce scales, loricas or walls tightly appressed to the protoplast. Those representatives in the St. Croix generally form loricas of cellulose and pectin, or occasionally internal silica skeletons. The lorica is a vase-shaped structures, surrounding a bi-flagellate cell of somewhat smaller size. Many species form colonies in which progressively older loricas are located toward the base. This is achieved by the retention of the daughter cell within the parent lorica. Variations in the size and shape of the lorica base contribute to differences in colony form.

PRINCIPAL FEATURES OF THE DINOFLAGELLATE CELL (PYRRHOPHYTA, DINOPHYCEAE)

Representatives of this class are unicellular, biflagellate organisms in which the cell is generally enclosed in a cellulose theca. The flagellae are dissmilar, one being located in a transverse groove (cingulum), the other in a longitudinal groove directed posteriorly. The combined action of the two flagellae causes the cell to rotate as it moves forward. The nucleus is large and located in the centre of the cell.

The wall covering the dinoflagellates, correctly termed the amphiesma, is divided into plates, sometimes clearly visible under the light microscope. In some species, eg. Ceratium, a considerable amount of morphological variation is common. In addition, some species form chains, which may add to the apparent morphological diversity.

COLLECTION, PRESERVATION AND CLEANING PHYTOPLANKTON SAMPLES

Phytoplankton samples are routinely collected by means of fine mesh nets, or with various kinds of water bottles. While some phytoplankton may be undamaged by net tows, it is generally more satisfactory to collect delicate phytoplankton in water bottles.

It is essentail to undertake initial identification of phytoplankton immediately following collection. Mucilage pads, protoplasmic strands and other intercellular connections are generally fragile, and tend to break down shortly after collection. While preservatives such as neutralized formalin are commonly used for phytoplankton, they tend to damage delicate structures, and may thwart later attempts at identification.

On occasion it may be necessary to remove the cell contents in order to see clearly the details necessary for identification. Unfortunately the process for removal of organic matter involves the use of hazardous materials. SUCH PROCEDURES SHOULD THEREFORE BE CARRIED OUT IN A FUME HOOD, EXERCISING ALL THE NORMAL PRECAUTIONS FOR THE USE OF SUCH SUBSTANCES.

Organic matter is removed from concentrated phytoplankton sample be gentle heat in concentrated nitric or hydrochloric acid and potassium dichromate. Alternatively, soaking in cold "Chromerge" (a commercial sulphuric acid/potassium dichromate solution) may be substituted for the heat treatment. The latter treatment takes a little longer to destroy all the organic matter. In either case, treatments are repeated until the solution no longer turns green. Spend oxidant is removed by centrifuging the sample and decanting the supernatant. The cleaned sample is suspended in a small volume of distilled water, to which a few milliliters of formalin may be added to prevent microbial growth during storage. Cold nitric acid alone, or 30% hydrogen peroxide, may also be used for cleaning purposes.

Permanent slides may be prepared by drying a drip of the cleaned sample on a microscope slide. When completely dry, a high refractive index mounting medium such as Hyrax or Pleurax (Hanna, 1949) and a cover glass are added. To prevent shrinkage of the dried medium with time, it is necessary to seal arcund the edge of the cover glass with nail polish, or a similar preparation. Slides prepared in this way consist almost completely of silica remains, and are essentially permanent. Although the preparation procedures are laborious, the improvement in clarity of the structures in cleaned preparations is always a delight.

THE ST. CROIX ESTUARY

Mean tidal amplitude at the head of the estuary is 6.1 m (Lakshminaryana, 1983). In conjunction with the considerable discharge of the St. Croix, the extreme tidal amplitude contributes to high suspended loads at certain times of the year. For example, in November 1979 and February 1980, 80% of surface insolation was attenuated by 5 m (Lakshminaryana, 1983). Annual temperature and salinity variations tend to be sinusoidal, with maximum temperatures in late August or early September. Salinities in the area increase from April or May, during the spring freshet, until October. The ranges of surface and bottom salinities at St. Andrews are 5.7 and 1.5 0/00 respectively (Thomas, 1983). These variations tend to decrease through Passamaquoddy Bay toward the Bay of Fundy.

In most temperate and cold-temperate marine and freshwater environments the phytoplankton population exhibits both quantitative and qualitative seasonal variations. In the St. Croix, overall population increases occur in both spring and fall, generally May and August. The

more dramatic increases coincide with periods of water column stability. Presumably because of the large tidal amplitude, coupled with considerable flow in the St. Croix, these seasonal maxima develop in a very heterogeneous manner. Thus at any given depth the estuary is composed of patches of water supporting different quantities of phytoplankton (Figures 3 and 4).

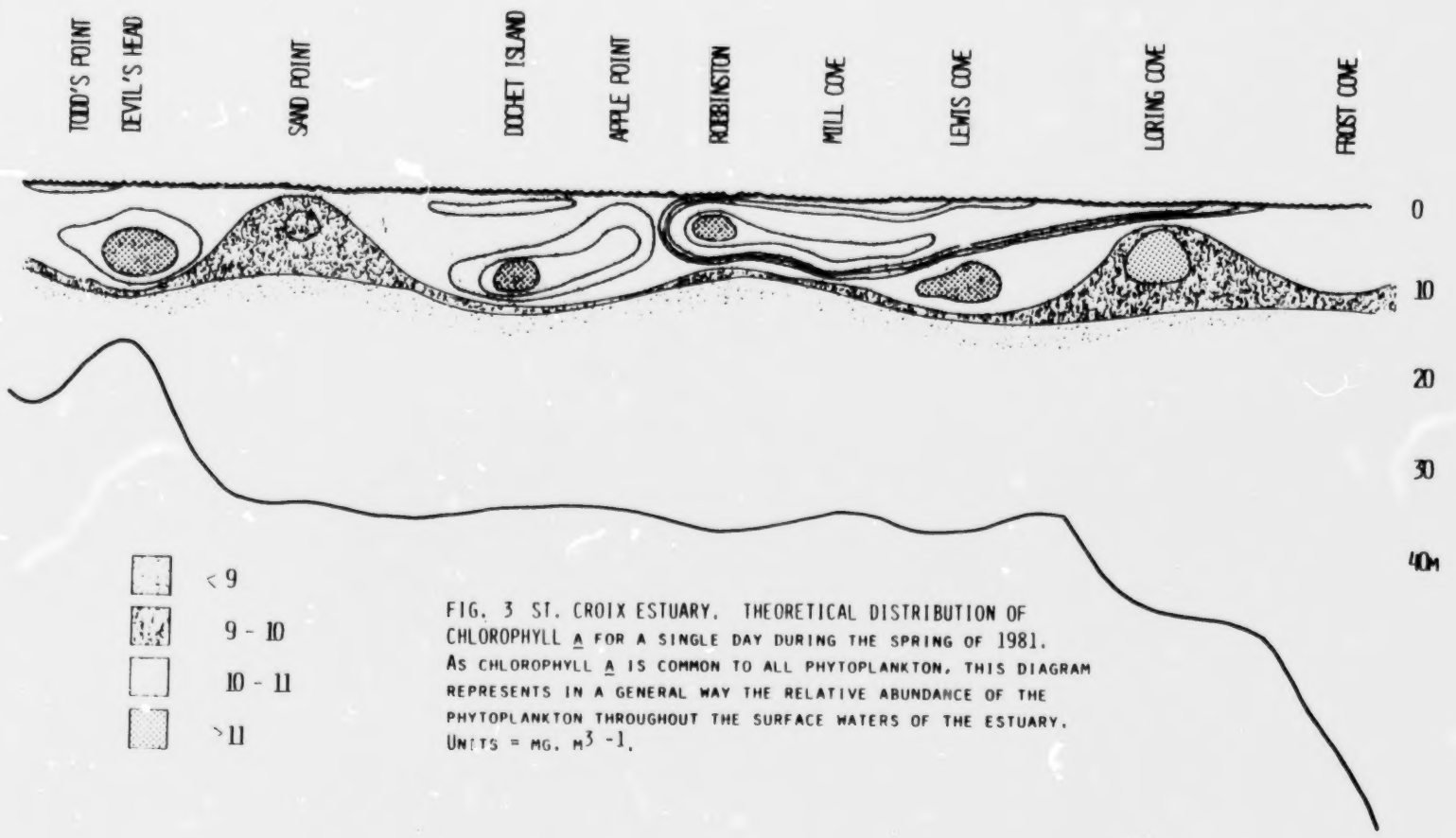


FIG. 3 ST. CROIX ESTUARY. THEORETICAL DISTRIBUTION OF CHLOROPHYLL A FOR A SINGLE DAY DURING THE SPRING OF 1981. AS CHLOROPHYLL A IS COMMON TO ALL PHYTOPLANKTON, THIS DIAGRAM REPRESENTS IN A GENERAL WAY THE RELATIVE ABUNDANCE OF THE PHYTOPLANKTON THROUGHOUT THE SURFACE WATERS OF THE ESTUARY. UNITS = MG. M^{3} $^{-1}$.

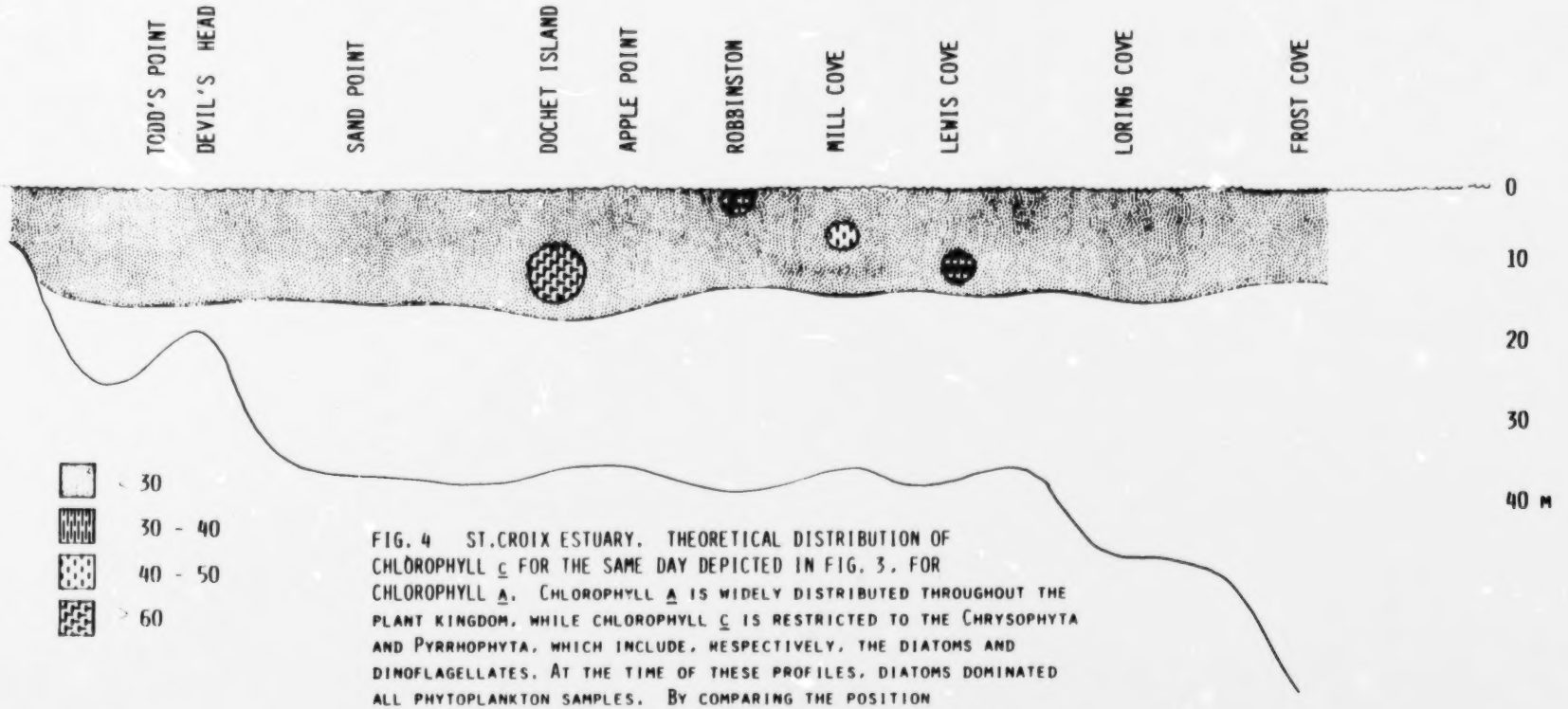


FIG. 4 ST.CROIX ESTUARY. THEORETICAL DISTRIBUTION OF CHLOROPHYLL c FOR THE SAME DAY DEPICTED IN FIG. 3, FOR CHLOROPHYLL A. CHLOROPHYLL A IS WIDELY DISTRIBUTED THROUGHOUT THE PLANT KINGDOM, WHILE CHLOROPHYLL C IS RESTRICTED TO THE CHRYSOPHYTA AND PYRRHOPHYTA, WHICH INCLUDE, RESPECTIVELY, THE DIATOMS AND DINOFLAGELLATES. AT THE TIME OF THESE PROFILES, DIATOMS DOMINATED ALL PHYTOPLANKTON SAMPLES. BY COMPARING THE POSITION OF THE CHLOROPHYLL C MAXIMA WITH THE REGIONS OF HIGH CHLOROPHYLL A CONCENTRATION, AN INDIRECT PROFILE MAY BE OBTAINED OF THE RELATIVE DISTRIBUTION OF THE DIATOMS WITHIN THE ESTAURY. UNITS = MG. M^{3-1}.

KEY TO THE MAJOR SUBSECTIONS OF THE PHYTOPLANKTON

1....Frustules composed of two silica planes or valves, epitheca and hypotheca, (one fitted inside the other), the two surrounded by a connecting bank (girdle or cingulum).....2

.....Individual cells within a vase-shaped wall (lorica), under phase-contrast cells usually clearly biflagellate. Colonies formed by the retention of the tail of one lorica within the mouth of the subtending lorica .....Section 22, p 51

...Solitary cells, biflagellate, prominent horizontal groove (usually clearly visible), cells generally encased within a stout wall with clearly defined plates. Walls commonly projected into prominent horns and spines.....Section 23, p 52

2....Frustules in chains or colonies, well ordered or randomly arranged, sometimes embedded in mucilage 3

.....Frustules solitary.....11

3....Frustules in distinct chains, not united by mucilage threads, but rather linked by opposing sets of long spines
.....Section 1, p 15

.....Frustules otherwise connected.....4

4....Frustules connected to one another by mucilage threads, forming straight or gently curving chains.....Section 2, p 18

.....Frustules otherwise connected.....5

5....Frustules in straight or zig-zag chains, individual cells connected by MUCILAGE PADS between adjacent spines or elevations (see Figure 2, 19 & 20).....Section 3, p 18

.....Frustules otherwise connected.....6

6....Individual frustules needle-shaped, some forms with strands of frustules in which extensive sections overlap. Means of attachment not visible (cells of this group often occur individually)
.....Section 4, p 21

.....Frustules otherwise connected.....7

7....Chains of cylindrical frustules, sometimes markedly barrel-shaped, not connected by arrays of fine spines
.....Section 5, p 21

.....Chains of bead-like, rectangular, or lens-shaped frustules, often connected by arrays of fine teeth or spines.
.....Section 6, p 23

.....Frustules otherwise arranged.....8

8....Frustules randomly arranged with no apparent pattern, often embedded in a mucilagenous mass.....Section 7, p 24

.....Frustules arranged differently.....9

9....Frustules forming star-shaped colonies, or partly forming such a pattern.....Section 8, p 27

.....Frustules arranged in some other pattern.....10

10...Frustules box-shaped or rectangular, joined corner to corner by mucilage pads (not joined by pads between elevations ... ..See Figure 4, 19 & 20).....Section 9, p 27

.....Frustules elongated, joined side-by-side into ribbon-like strands.....Section 10,p 30

.....Frustules not as above.....11

11...Frustules often seen in valve view (as circular structures) with small spines on valve face and/or margin.....Section 11,p 31

.....Frustules as above, but lacking spines.....Section 12,p 33

.....Frustules of different structure.....12

12...Frustules most frequently seen in girdle view. The face and/or margin bearing stout spines or massive projections (elevations) .....Section 13,p 36

.....Frustules of different structure.....13

13...Frustules sigmoid, or slightly sigmoid in outline .....Section 14,p 39

.....Frustules not sigmoidal in outline.....14

14...Frustules asymmetrical in at least one plane.....Section 15,p 41

.....Frustules symmetrical.....15

15...Frustules needle-shaped, many times longer than broad, (sometimes united, side by side, into ribbon-like chains).....Section 16, p 43

.....Frustules only a few times longer than broad.....16

16...Frustules with a narrow strip, the length of the cell, devoid of ornamentation, sometimes also with a median line (raphe) .....Section 17,p 45

.....Frustules with an obvious strip devoid of ornamentation.....17

17...Frustules with a central band, the <u>width</u> of the cell, devoid of ornamentation.....Section 18,p 45

.....Cells without such a central region.....18

18...Frustules with a large central area or areas, devoid of ornamentation, extending towards the apices, interrupting the pattern of the striae.....Section 19,p 47

.....Frustules with a central region of different structure.....19

19...Striae in the central region of the valve of the same g e n e r a l length and form.....Section 20,p 47

.....Striae not as above.....20

20...Striae in the central region shorter than those on either side .....Section 21,p 48

.....Striae not so arranged. <u>Nitzschia graeffi</u> Grun. Figure 108 p 74

SECTION 1. (Chaetoceros).

Frustules are usually seen in girdle view, chains with obvious spines and bristles extending well beyond the margin of the valve. Chains straight, curved, twisted or matted.

1....Chains straight.....3

.....Chains curved.....2

2....Chains, spiral. Chaetoceros debilis Cl. Figure 5

.....Chains, gently curved.
Chaetoceros curvisetus Cl. Figure 6 a-c

3....Spines of adjoining cells basally fused up to the equivalent of one cell length.
Chaetoceros decipiens Cl. Figure 7 a & b

.....Spines not so joined.....4

4....Spines of terminal frustules notably stouter and longer than those on the intervening frustules.
Chaetoceros laciniosus Schutt. Figure 8

.....Spines not as above.....5

5....Sides of the frustules sculptured.
Chaetoceros constrictus Gran. Figures 9 a & b

.....Sides of frustules smooth. Chaetoceros teres Cl. Figure 9c

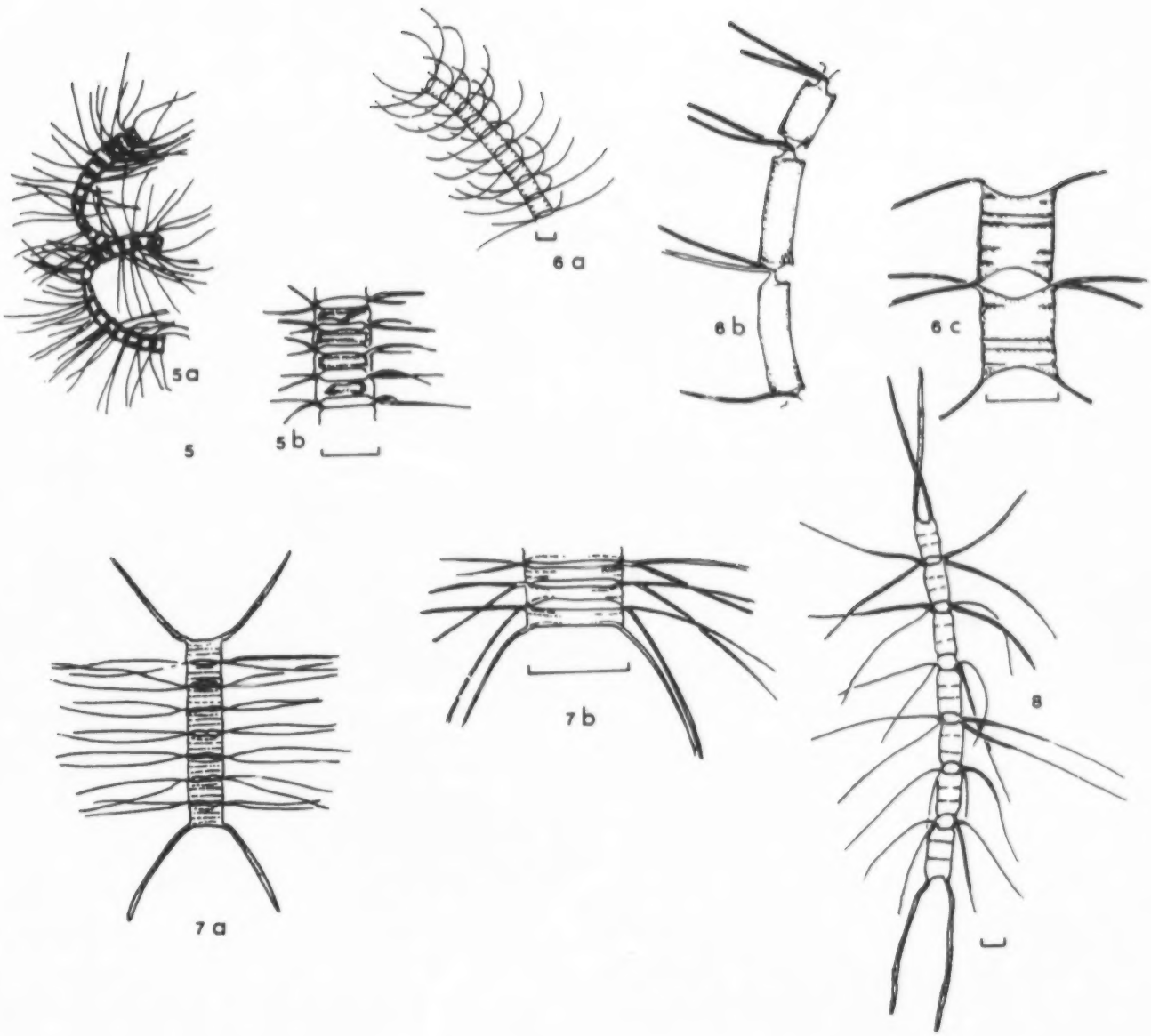


Figure 5. Chaetoceros debilis Cl. a) typical chain. b) detail of part of a chain. bar = 36 µm
Figure 6. Chaetoceros curvisetus Cl. a) typical chain bar = 7 µm b) chain in narrow girdle view. c) detail of part of a chain. bar = 20 µm
Figure 7. Chaetoceros decipiens Cl. a) complete chain b) detail of part of a chain. bar = 5 µm
Figure 8. Chaetoceros laciniosus Schutt Typical chain, bar = 12 µm

Figures 5 - 7, and 8 after Cupp (1943).

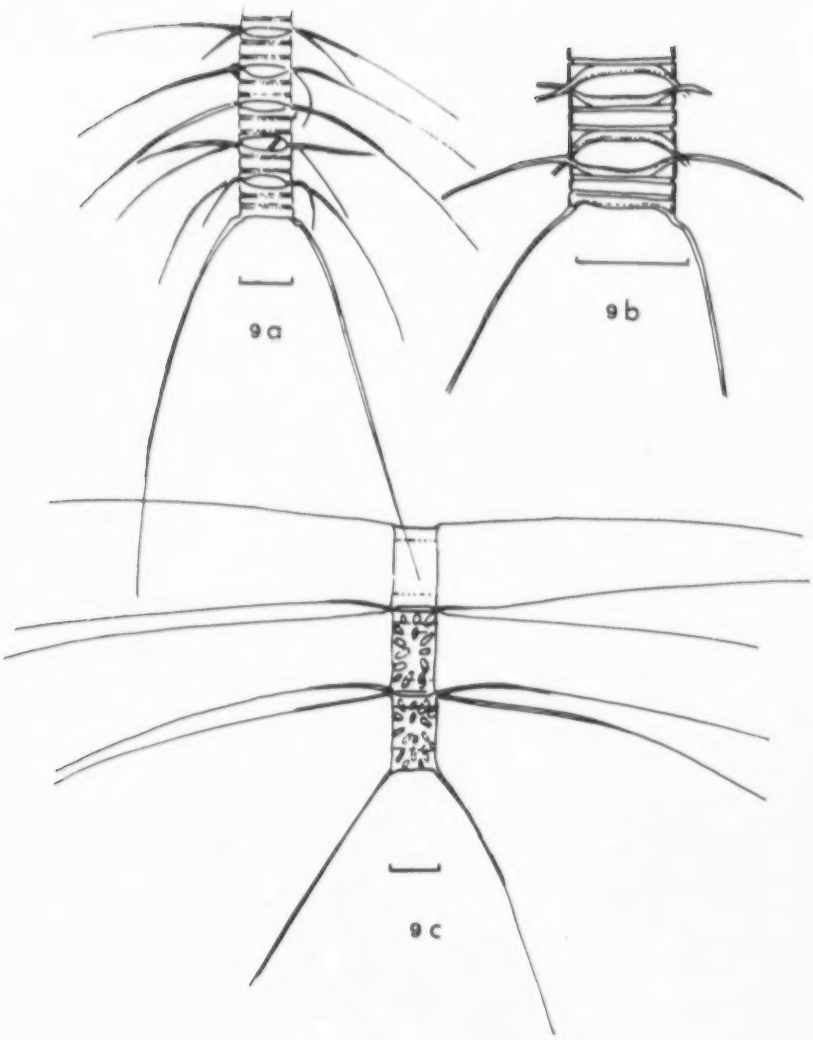


Figure 9a Chaetoceros constrictus Gran. typical chain. bar = 26 µm
Figure 9b detail of two frustules. bar = 27 µm
Figure 9c Chaetoceros teres Cleve. Typical frustules. bar = 30 µm

Figures 9a and 9b after Cupp (1943), Figure 9c after Hendey (1964).

SECTION 2

Frustules united by one or more mucilage threads, forming straight or gently curving chains.

1....Frustules joined by a single thread.....2

.....Frustules joined by 4 - 7 threads. Coscinosira polychorda Gran. Figures 10 a & b

2....Box shaped frustules with angular corners, producing an 8-sided appearance. Thalassiosira nordenskioldii. Cl. Figure 11

.....Frustules with more rounded corners.....3

3....Frustules forming short, strong chains, as a result of a single thick mucilage thread. Thalassiosira gravida. Cl. Figures 12 & 12a

.....Chains not as above.....4

4....Frustules with minute spines, or apparently without spines Thalassiosira baltica. (Grunow) Östenfeld. Figures 13 & 13a

.....Frustules with well developed spines and spinulae. Thalassiosira decipiens. (Grun.) Jrg. Figure 14

SECTION 3

Frustules attached by means of mucilage pads between prominent corner processes (horns or elevations).

1....Frustules forming straight or zig-zag colonies.....2

.....Frustules attached by short processes, forming curved chains. Eucampia zoodicus. Ehr. Figure 15

2....Massive setae and elevations on valve face. Biddulphia aurita. (Lyng.) Bréb. & God. Figure 16

.....Elevations less strongly developed. Biddulphia alternans. (Bail.) V.H. Figure 17

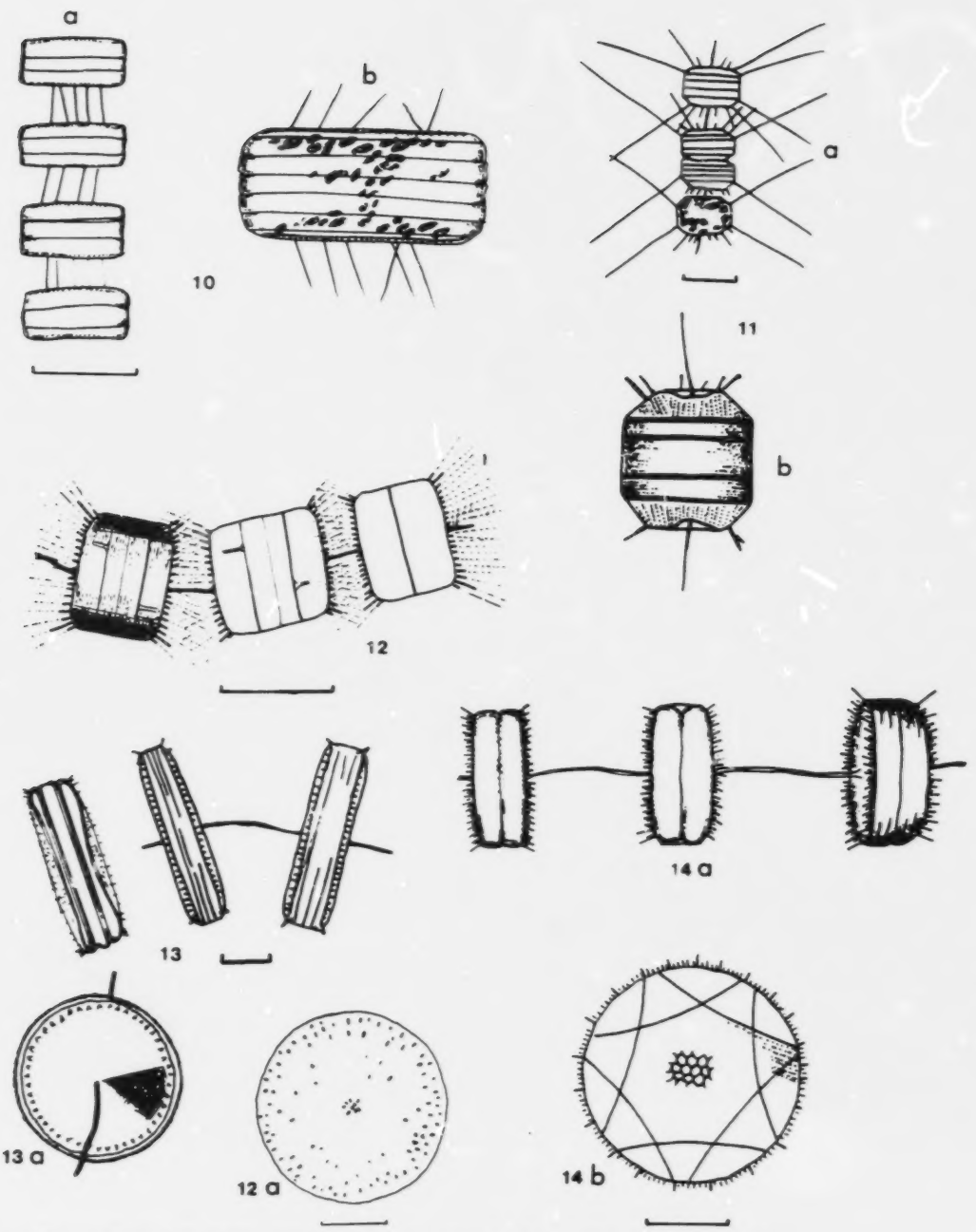


Figure 10. Coscinosira polychorda Gran. a) Chain of cells. bar = 50 µm b) detail of a single frustule

Figure 11. Thalassiosira nordenskioldii Cl. a) chain with a pair of recently divided frustules. bar = 8 µm b) showing details of the frustule.

Figure 12. Thalassiosira gravida Cl. Chain of cells. bar = 30 µm

Figure 12a. Thalassiosira gravida. valve view. bar 10 µm

Figure 13. Thalassiosira baltica (Grunow) Östenfeld. Frustules in girdle view. bar = 25 µm

Figure 13a. Thalassiosira baltica. valve view.

Figure 14. Thalassiosira decipiens (Grun.) Jrg. a) frustules. b) single frustule, showing the pattern of sculpturing, with a small area in detail (inset). bar = 12 µm

All Figures after Cupp, (1943), except 13 and 14b after Hendey (1964)

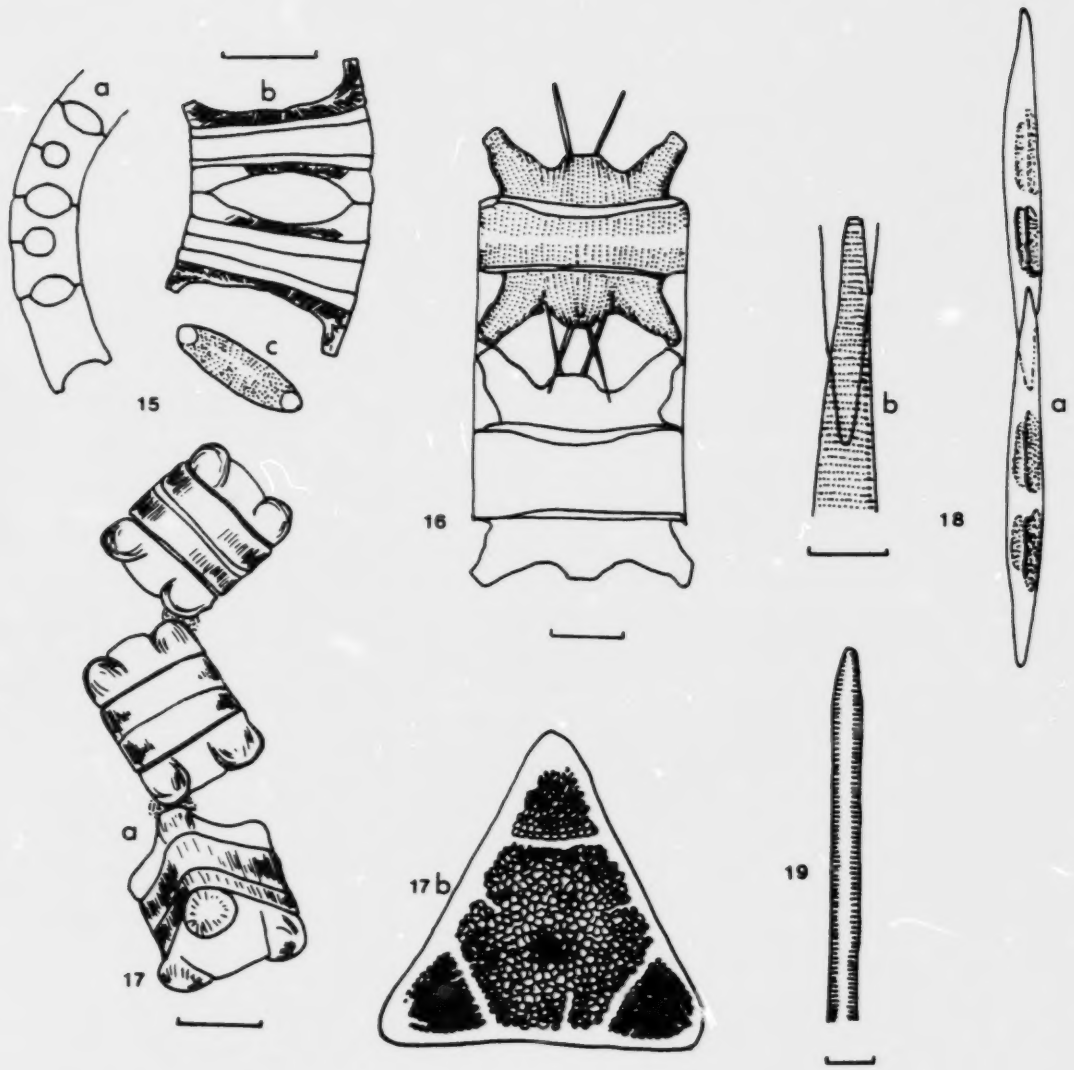


Figure 15. Eucampia zoodicus Ehr. a) part of a chain of cells. b) two frustules in girdle view, showing the arrangement of sculpturing. bar = 22 µm. c) valve view of a single frustule.

Figure 16. Biddulphia aurita (Lyng.) Breb. & God. Two frustules in broad girdle view, with the arrangement of sculpturing shown on the upper frustule. bar = 17 µ.

Figure 17. Biddulphia alternans (Bail.) V.H. a) chain in girdle view. bar = 17 µm. b) valve view of a frustule, showing the arrangement of sculpturing.

Figure 18. Nitzschia seriata Cl. Valve view of two frustules, showing the chromatophores. b) detail of part of a single frustule, valve view, showing striae. bar = 7 µm.

Figure 19. Synedra fasciculata (Ag.) Ktz. v. fasciculata. Part of a frustule, in valve view, showing the broad pseudoraphe. bar = 7 µm.

All Figures after Cupp (1943), except for Figure 19 (Schmidt, 1874-1944) and 17b (original).

SECTION 4

Individual frustules needle shaped, including forms with strands of cells in which extensive sections overlap. Frustules sometimes solitary.

.....Frustules with two relatively large chloroplasts. Chains of 4 - 8 overlapping frustules not uncommon. Nitzschia seriata. Cl. Figure 18

.....Frustules with minute marginal striae and a broad pseudoraphe. Often solitary. Synedra fasiculata (Ag.) Ktz. v. fasciculata. Figure 19

SECTION 5

Chains of cylindrical frustules, sometimes markedly barrel-shaped, not connected by arrays of fine spines.

1....Frustules at least partly connected by a minute spine.....3

.....Frustules arranged end-to-end with no apparent connecting spine...2

2....Long, narrow frustules, entire valve face abutting that of the adjacent frustule. Leptocylindricus danicus Cl. Figure 20

.....Frustules short, barrel-shaped; adjacent valve faces not touching. Bacteriosira fragilis Gran. Figure 23.

3....Spine more or less central, Rhizosolenia fragilissima Berg. Figure 21

.....Spine from the side of the valve face. Rhizosolenia delicatula. Figure 22

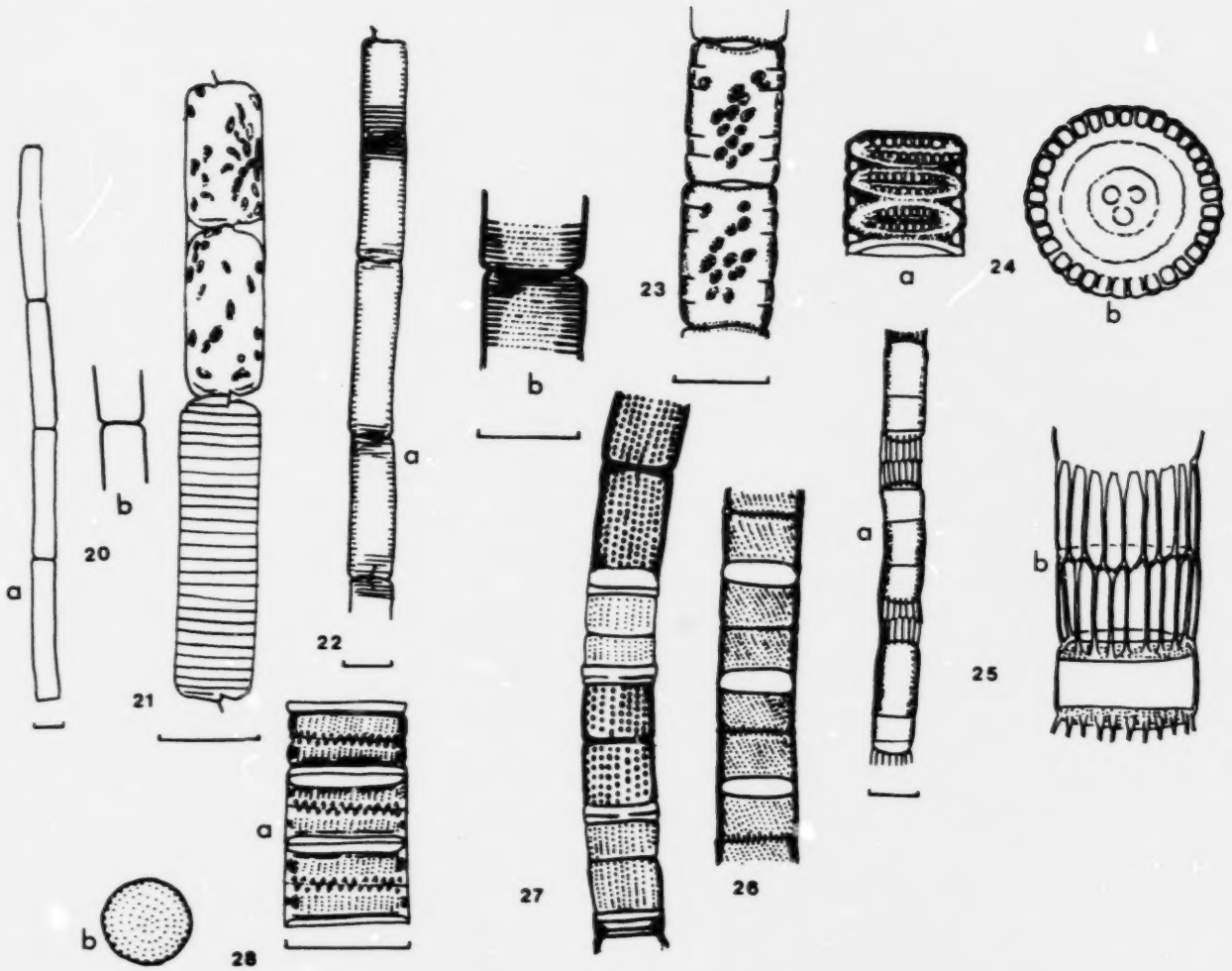


Figure 20. Leptocylindricus danicus Cl. a) section of a chain, bar = 10 µm. b) detail of end walls
Figure 21. Rhizosolenia fragilissima. Berg.
Figure 22. Rhizosolenia delicatula Cl. a) part of a chain showing the intercalary bands. bar = 10 µm. b) parts of two frustules showing intercalary bands and the junction of the two valve faces.
Figure 23. Bacteriosira fragilis Gran. Valve view of two frustules showing the chromatophores. bar = 16 µm.
Figure 24. Paralia sulcata (Ehr.) Cl. a) vegetative frustules, girdle view. b) valve view
Figure 25. Skeletonema costatum (Grev.) Cl. a) vegetative frustules. bar = 10 µm. b) showing details of the marginal spines, and the junction between the two frustules.
Figure 26 Melosira italica (Ehr.) Ktz. typical chain, (girdle view).
Figure 27. Melosira islandica O.M. typical chain (girdle view).
Figure 28. Melosira distans (Ehr.) Ktz. a) typical chain. bar = 18 µm. b) valve view of single frustule.

Figures 20 - 22, and 25 after Cupp (1943), 23, LeBour (1930), 26 - 28, Cleve-Euler (1968).

SECTION 6

Narrow chains of bead-like or rectangular to lens-shaped frustules, often with interconnecting spines or "teeth".

1....Chains composed of small bead-like frustules joined by numerous fine spines. Skeletonema costatum (Grev.) Cl. Figure 25

.....Chains otherwise.....2

2....Frustules generally capsule-like, with only the centre of the valve face (end in girdle view) joining with that of adjacent valves, giving rise to constrictions between frustules or frustule groups 6

.....Chains not as above.....3

3....Chains of frustules with a box and groove appearance.....4

.....Lens-shaped frustules with bead-like appearance Paralia sulcata (Ehr.) Ktz. Figure 24

4....Striae giving the chain a distinct spiral. Spines linking adjacent frustules of similar length. Melosira italica (Ehr.) Ktz. Figure 26

.....Striae forming less pronounced spirals. Adjacent frustules apparently joined by spines of two distinct lengths. Frustules 4-30 µm in diameter. Melosira granulata (Ehr.) Ralfs. Figure 35

.....Chains as above but narrower, frustules 4 - 5.2 µm in diameter, 15 - 20 µm in length Melosira granulata v. angustissima O.M. Figure 36

.....Chains otherwise.....5

5....Striae parallel with the longitudinal axis of the chain. Frustules a maximum of 30 µm (end to end) and 16 µm in diameter. Melosira islandica O. M. Figure 27

.....Chains of smaller frustules, a maximum of 11 µm end to end Melosira distans (Ehr.) Ralfs. Figure 28

.....Chains otherwise.....6

6....Frustules almost subhemispherical.....7

.....Frustules more elongated.....8

7....Frustules with distinct collar. Melosira nummuloides C.A.Ag. Figure 30

.....Long chains, frustules often united in pairs; frustules circular to subhemisperical, 30 - 40 µm in diameter. Frequent on rocks, attached by mucilage threads. Melosira moniliformis (Müll.) C.A.Ag. Figure 32

8....Tight, strong chains, parallel sides; punctae not obvious; part of the valve end flattened, up to 70 µm end to end. Melosira lineata (Dillw.) C.A. Ag. Figure 31

.....Chains long and narrow, frustules up to 20 µm in length. A small area of the valve face (end in girdle view) flattened against that of the adjacent frustule. Valve mantle very deep. Frustules finely punctate only under high power. Melosira juergensii C.A.Ag. Figure 29

SECTION 7

Frustules with no apparent arrangement, often embedded in a mucilagenous mass.

1....Box-shaped frustules, joined by fine intertwining bristles. Chaetoceros socialis. Laud. Figure 33

.....Small ovoid frustules, embedded in mucilage, minute marginal spines. Thalassiosira subtilis (Osten.) Gran. Figure 34

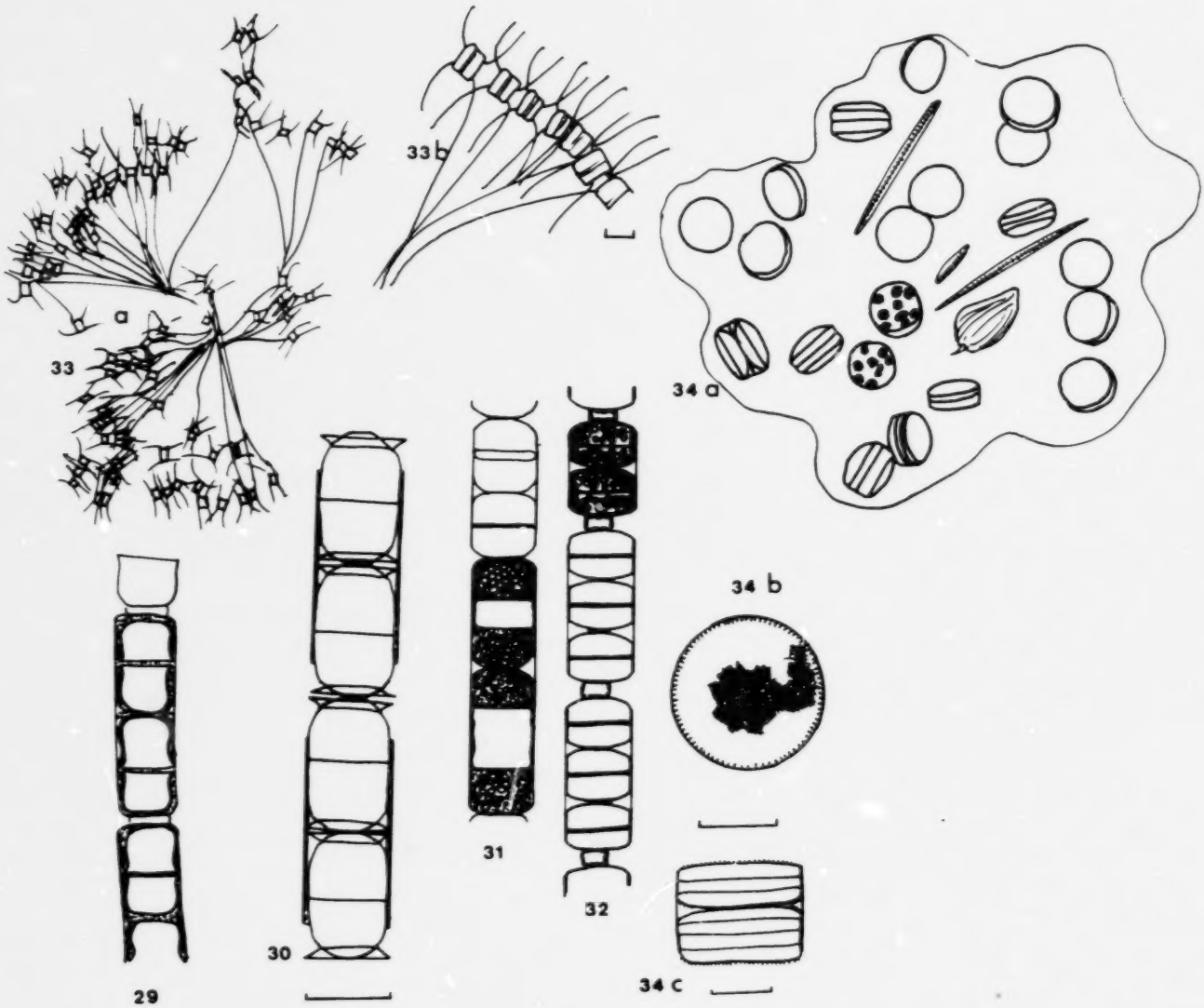


Figure 29. Melosira juergensii C.A.Ag. Section of a typical chain
Figure 30. Melosira nummuloides C.A.Ag. Section of a typical chain. bar = 13 µm.
Figure 31. Melosira lineata (Dillw.) C.A.Ag. typical chain (girdle view)
Figure 32. Melosira moniliformis (Müll.) C.A.Ag.
Figure 33. Chaetoceros socialis Laud. a) colony. b) part of a chain bar = 8 µm.
Figure 34. Thalassiosira subtilis (Osten.) Gran. a) frustules in a mucilagenous mass. b) single frustule in valve view, showing the pattern of sculpturing on the valve face. bar = 14 µm. c) two frustules in girdle view, showing the small marginal spines, bar = 10 µm.

Figures 29 - 30, and 32c, after Cleve-Euler (1968), 30 after Hustedt (1930), 33 and 34a, after Cupp (1943).

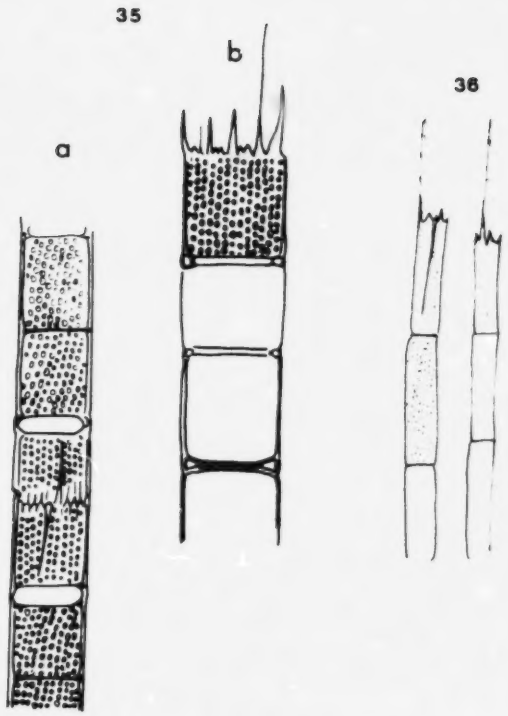


Figure 35. Melosira granulata (Ehr.) Ralfs. a) typical chain girdle view. b) section of chain showing details of spines (frustules range from 4 - 30 µm in diameter).

Figure 36. Melosira granulata v. angustissima (O. M.), section of a typical chain with long terminal spines. Frustules usually 2.5-4 µm in diameter.

SECTION 8

Frustules forming star-shaped colonies, or partly forming such a pattern.

1....Septa and/or striae present.....3

.....Septa and/or striae absent.....2

2....Narrow frustules, both apices inflated, Asterionella formosa Hassall. Figure 37

.....Narrow frustules, attachment end only inflated, the other end tapered. Asterionella japonica Cl. Figure 38

3....Frustules with two or three septa. Tabellaria fenestrata (Lyngb.) Ktz.v. fenestrata Figure 40 & 41 (Consult Patrick & Reimer, 1966; Koppen, 1975, for additional details).

.....Frustules with short, marginal striae, ends slightly produced. Diatoma elongatum Ag. Figure 39

SECTION 9

Frustules more or less box-shaped or rectangular, joined corner to corner by mucilage pads to form zig-zag chains.

1....Septa (s in Figure 45) present.....3

.....Septa absent.....2

2....Frustules cigar-shaped, ends rounded, little variation in width; numerous small circular chromatophores. Thalassionema nitzschioides. Grun. Figure 42

.....Cells with slightly inflated apices. Diatoma elongatum Ag. Figure 39

3....Septa bent at some point along their length.....4

.....Septa at most only slightly curved, in valve view, apices slightly inflated.....5

4....Septa forming a hook about the middle of the frustule. Grammatophora angulosa Ehr. Figure 45

.....Pairs of septa slightly inflated near the base. Grammatophora marina (Lyng.) Ktz. Figure 44

5....Short, box-shaped frustules; short slightly undulate septa. In valve view, median area abruptly widened, terminal inflations slightly capitate.
Tabellaria flocculosa (Roth) Ktz.v. flocculosa. Figure 43

.....Frustules rectangular, septa straight. Tabellaria fenestrata (Lyng.) Ktz. Figure 40 & 41

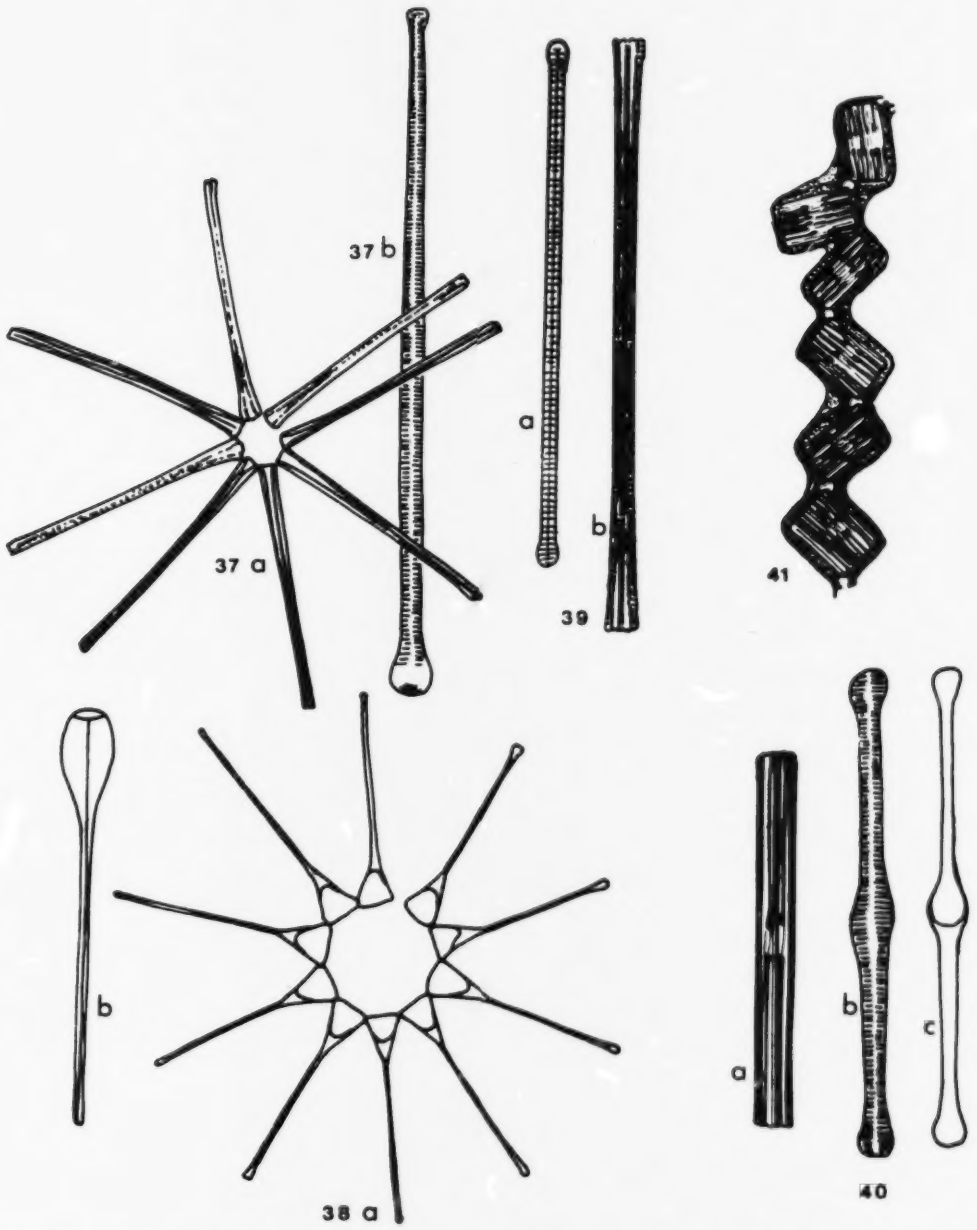


Figure 37. Asterionella formosa Hassall. a) colony. b) single frustule, valve view. x 1500.

Figure 38. Asterionella japonica Cl. a) colony. b) frustule, valve view. x 650

Figure 39. Diatoma elongatum Ag. a) valve view. b) girdle view x 1000

Figure 40. Tabellaria fenestrata (Lyngb.) Ktz. v. fenestrata a) girdle view. b) valve view. c) girdle band x 1000

Figure 41. Colony of a varietal form of Tabellaria fenestrata v. fenestrata showing mucous attachment of individual frustules. x 1000.

Figures 37 and 38 after Cleve-Euler (1968). Figures 39 and 40 after Hustedt (1930, and 1985) respectively.

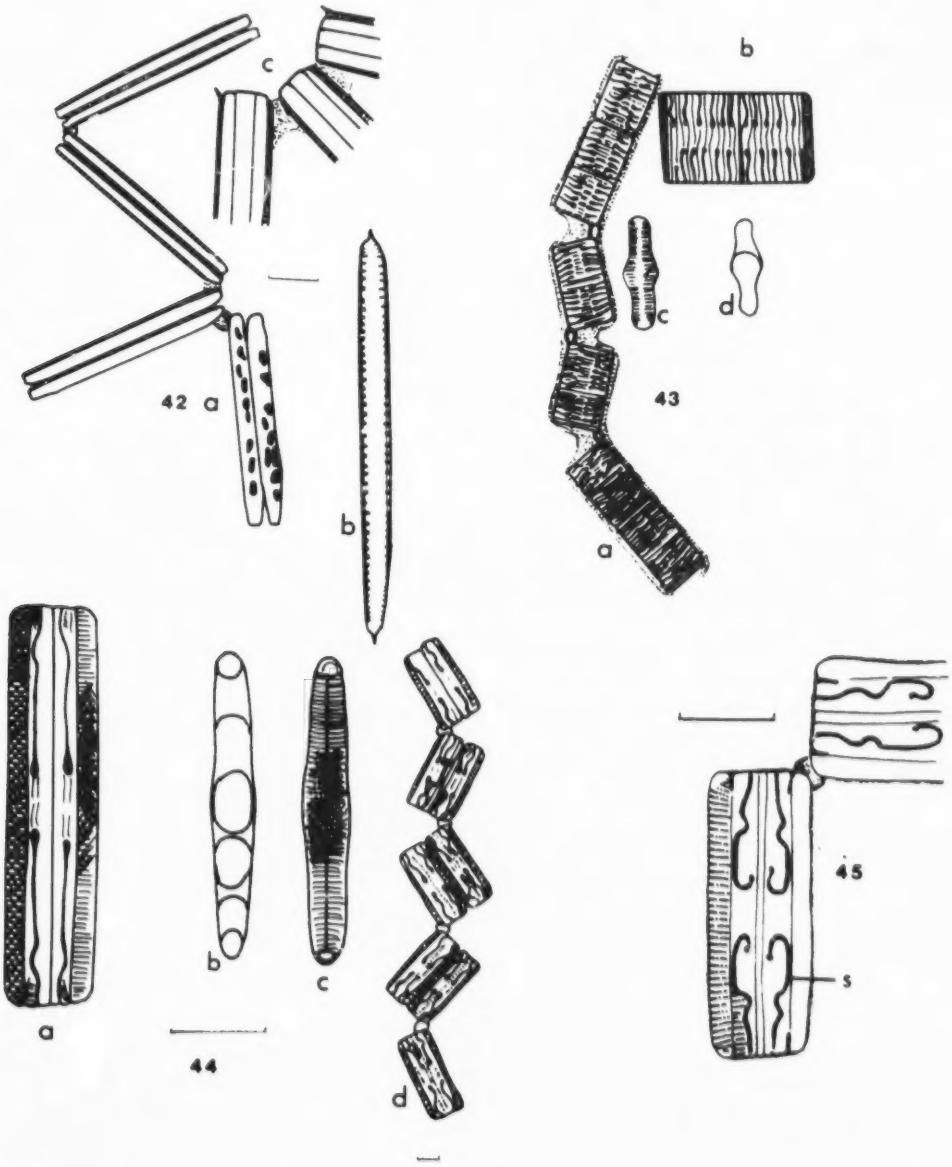


Figure 42. Thalassionema nitzschioides Grun. a) colony. b) single frustule, valve view. c) detail of frustule ends, girdle view. bar = 10 µm

Figure 43. Tabellaria flocculosa (Roth) Ktz. v. flocculosa a) colony. b) girdle view. c) frustule in valve view. d) girdle band. x 1000

Figure 44. Grammatophora marina (Lyng.) Ktz. a) frustule in girdle view. b) showing intercalary (internal) bands. c) valve view. d) chain of a small variety of G. marina. bars = 10 µm

Figure 45. Grammatophora angulosa Ehr. Valves in girdle view. bar = 10 µm

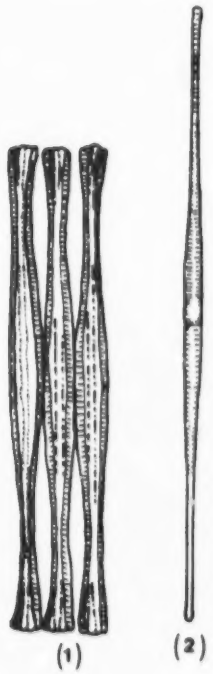
Figures 42, 44 and 45 after Cupp (1943). Figure 43 after Hustedt (1985).

SECTION 10

Frustules elongated, joined side-by-side into a ribbon-like colony.

1....Frustules in the ribbon inflated at the point of attachment to the neighbouring cell. Apices slightly rostrate (expanded) in valve view. Fragilaria crotonensis Kitton v. crotonensis. Figure 46 a

.....Frustules joined to neighbouring cells along their entire length. No median inflation. In valve view, frustule apices truncate. Fragilaria capucina Desm. v. capucina. Figure 46 b



46a

46b

Figure 46a(1) Fragilaria crotonensis Kitton v. crotonensis. valves in girdle view
Figure 46a(2) Fragilaria crotonensis v. crotonensis. valve view. x 1000
Figure 46b(1) Fragilaria capucina Desm. v. capucina. girdle view.
Figure 46b(2) Fragilaria capucina v. capucina. valve view. x 1000

After Hustedt (1930).

SECTION 11

Frustules usually seen in valve view (circular outline) with or without marginal spines.

1....Valve face divided into obvious sectors.....2

.....Valve face not so divided.....4

2....Valve face divided into 6 sectors. Actinophytus undulatus (Bail.) Ralfs. Figure 46

.....Valve face not as above.....3

3....Valve face with a broad pseudoraphe and many side chambers. Entire frustule not perfectly symmetrical. Campylodiscus fastuous Ehr. Figure 47

.....Valves not as above.....4

4....Valves with marginal striation only, central area may or may not appear punctate. Cyclotella operculata (Ag.) Ktz. Figure 48

.....Entire valve face sculptured.....5

5....Valve face often with spines and pores, either in the centre or arranged evenly throughout. Thallasiosira.....6

.....Valve face without marginal spines, or spines difficult to identify. Coscinodiscus (Section 12) .....p. 33

6....Valve face with or without a central pore, but other pores present in the valve face.....7

.....Valve face with 4 to 7 central pores, arranged radially Coscinosira polychorda Gran. Figure 49

7....Valve face with but a single prominent central pore.....8

.....Valve face with central and additional pores.....9

8....Valve face with spines originating on the margin but extending well beyond. In girdle view frustules with distinct shoulders. Thalassiosira nordenskioldii Cl. Figure 11

.....Valve face with shorter spines, but still extending well beyond the valve margin. Central pore difficult to see with the light microscope. In girdle view frustules with rounded margins. Thalassiosira decipiens (Grun.) Jrg. Figure 14

9....A series of pores in the centre of the valve face; additional pores spread throughout the valve face. Thalassiosira gravida Cl. Figure 12

.....Additional pores restricted to the margin of the valve face. Thalassiosira baltica (Grun.) Österi. Figure 13

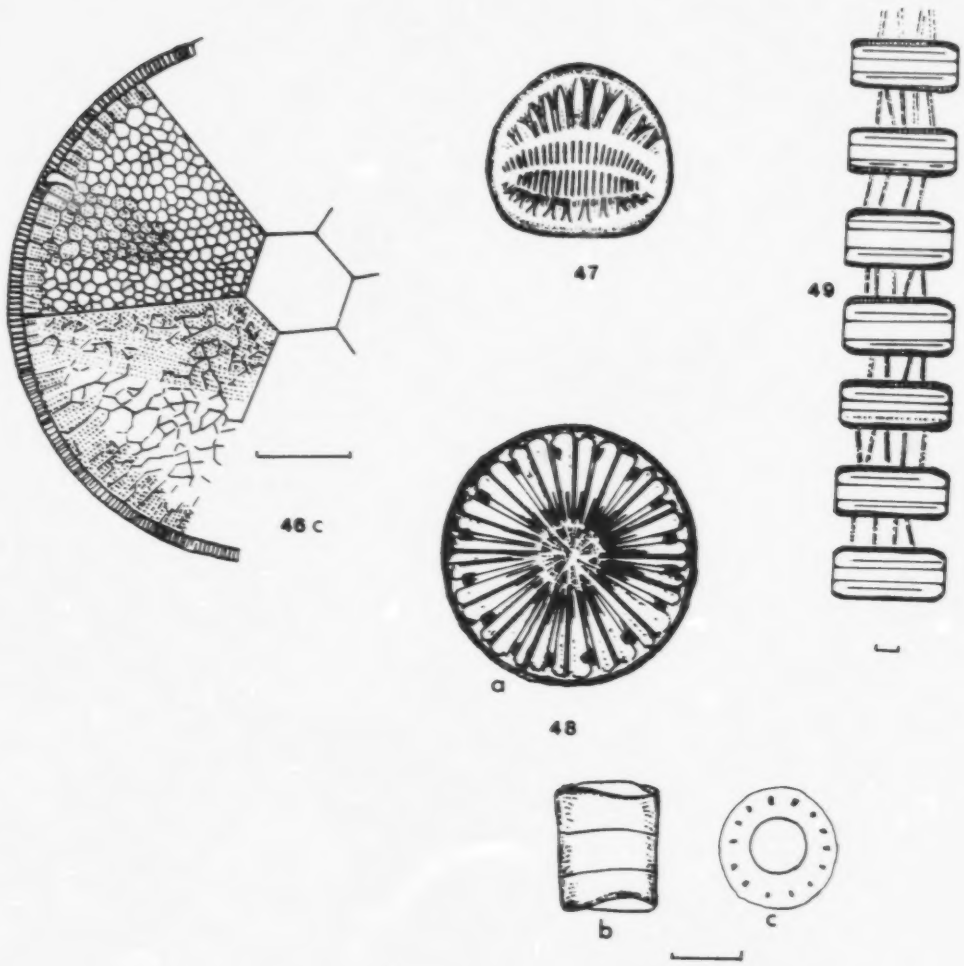


Figure 46c. Actinoptychus undulatus (Bail.) Ralfs. bar = 10 µm
Figure 47. Campylodiscus fastuosus Ehr.
Figure 48. Cyclotella operculata (Ag.) Ktz. a) valve view, detail b) and c) girdle and valve views respectively bar = 10 µm
Figure 49. Coscinosira polychorda Gran. chain (girdle view) bar = 18 µm

Figure 46c and 49 after Cupp (1943). Figure 48b and 48c after Cleve-Euler (1968). Figure 47 and 48a original.

SECTION 12 COSCINODISCUS

1....Valves with a distinct central rosette.....2

.....Valves lacking a rosette, or with an indistinct rosette.....3

.....Large valves, 160 - 200 µm in diameter, thin, delicate areolation, transparent central area, rosette entirely absent...Coscinodiscus concinnis W. Smith. (no Figure)

2....Valve with 3 to 6 dark, irregular thickenings in the centre ...Coscinodiscus stellaris Rop. Figure 50

.....Central rosette composed of 5 or fewer irregular areolae, somewhat larger than the others. Coscinodiscus oculus-iridis Ehr. Figure 51

3....Areolae in radial rows, or almost so.....4

.....Areolae not so arranged.....6

4....Areolae only slightly radial; generally freely arranged; cells small. Coscinodiscus nitidus Greg. Figure 54

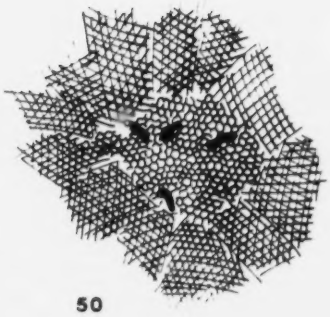
.....Frustule face not as above.....5

5....Valve margin distinct, and set off from the remainder of the face. Irregular rows of areolae. Coscinodiscus marginatus Ehr. Figure 54

.....Valve margin indistinct, areolae approximately the same size throughout the valve face. Coscinodiscus radiatus Ehr. Figure 52

6....Areolae in almost parallel rows, eccentric. Coscinodiscus excentricus Ehr. Figure 53

.....Areolae in distinct, straight rows. Coscinodiscus lineatus Ehr. Figure 55



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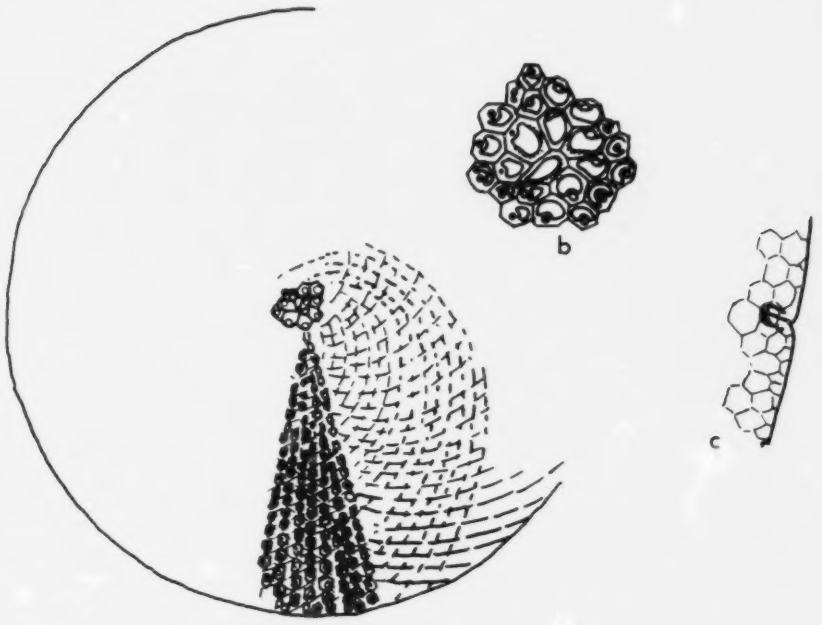

51 a

Figure 50. Coscinodiscus stellaris Rop. centre of frustule showing 4 irregular dark thickenings, diameter of valve normally about 100 µm
Figure 51. Coscinodiscus oculus-iridis Ehr. a) showing the pattern of areolae x 600 b) detail of areolae in the valve centre x 1000 c) section of valve margin x 1000

Figures 50 and 51 after Cupp (1943)

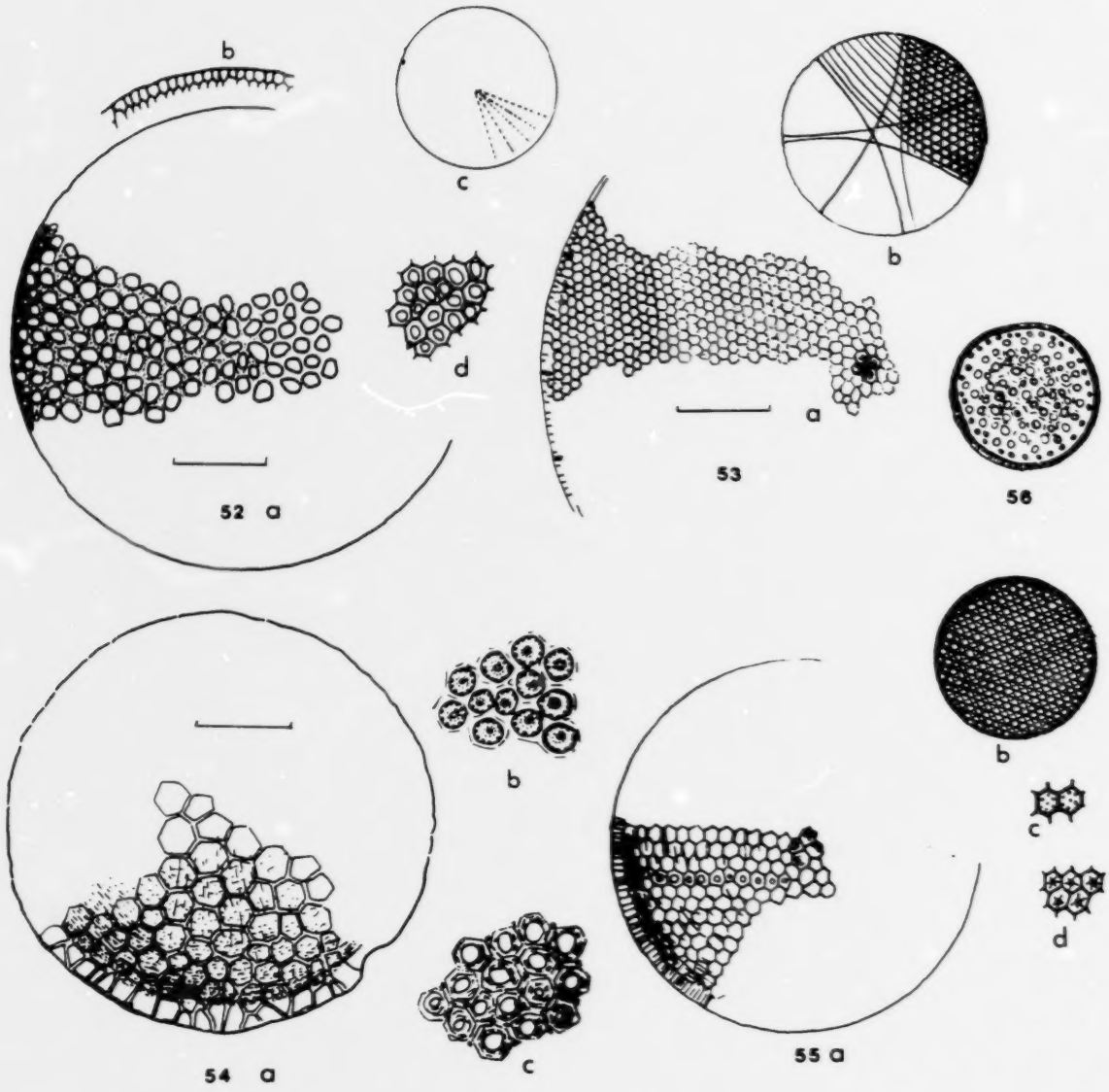

Figure 52. Coscinodiscus radiatus Ehr. a) section of valve showing the pattern of areolae. b) detail of the valve margin. c) diagrammatic representation of the areolae pattern. d) detail of the larger areolae near the valve centre.

Figure 53. Coscinodiscus excentricus Ehr. a) section of valve showing the pattern areolae. b) diagrammatic representation of valve sculpturing. bar = 10 µm

Figure 54. Coscinodiscus marginatus Ehr. a) showing the arrangement of the areolae. b) & c) details of areolae at different focus. bar = 10 µm

Figure 55. Coscinodiscus lineatus Ehr. a) Section of valve showing the pattern of areolae. b) diagrammatic representation of areolar pattern. c) & d) details of areolae at different focus.

Figure 56. Coscinodiscus nitidus Gregg. Valve view

Figures 52 - 55 after Cupp (1943)

SECTION 13

Frustules for the most part solitary, with an external process of some sort (spines, bristles of horns).

1....Cells with a tubular network forming or nearly forming a complete star.....2

.....Cells not as above.....3

2....Frustules with 6 spines, forming a star. Distephanus speculum (Ehr.) Haeckel Figure 57

.....Frustules with 4 to 6 spines, an imperfect star Dictyocha fibula* Ehr. Figure 58

3....Rectangular frustules with domed ends.....4

.....Frustules not as above.....5

4....Frustule end stongly inflated, each with a circlet of fine bristles or spines angled in the same direction. Corethron criophyllum Castracane. Figure 58

.....Frustule ends with a single robust spine parallel with the longitudinal axis, and small spines at the corners of the frustule. Ditylium brightwellii (West) Grun. Figure 60 & 61

5....Robust frusutles with the corners sometimes produced into horns...6

.....Frustules not as above.....7

6....Frustules with well developed horns (elevations); valve face (end) slightly inflated between the horns, usually bearing two spines. Biddulphia aurita (Lyng.) Breb. and God. Figure 16

.....Frustule faces only slightly inflated, valves triangular. Biddulphia alternans (Bail.) V.H. Figure 17

* Dictyocha belongs to the Class Chrysophyceae, together with Dinobryon (Section 22). It is placed here rather than in Section 22 simply to facilitate identification.

7....Frustule elongated, many times longer than broad.....8

.....Frustule not so elongated.....9

8....Frustule with terminal spines as long as or longer than cell length. Rhizosolenia setigera Brightw. Figure 62

.....Delicate frustules with fine short spines on the valve face (end). Rhizosolenia eriensis H.L. Smith. Figure 63

9....Small tubular frustules with flexible terminal spines. Cylindrotheca gracilis (Bréb.) Grun. Figure 65

.....Frustules as above, except with stout, inflexible terminal spines. Nitzschia longissima (Bréb.) Ralfs. Figure 64

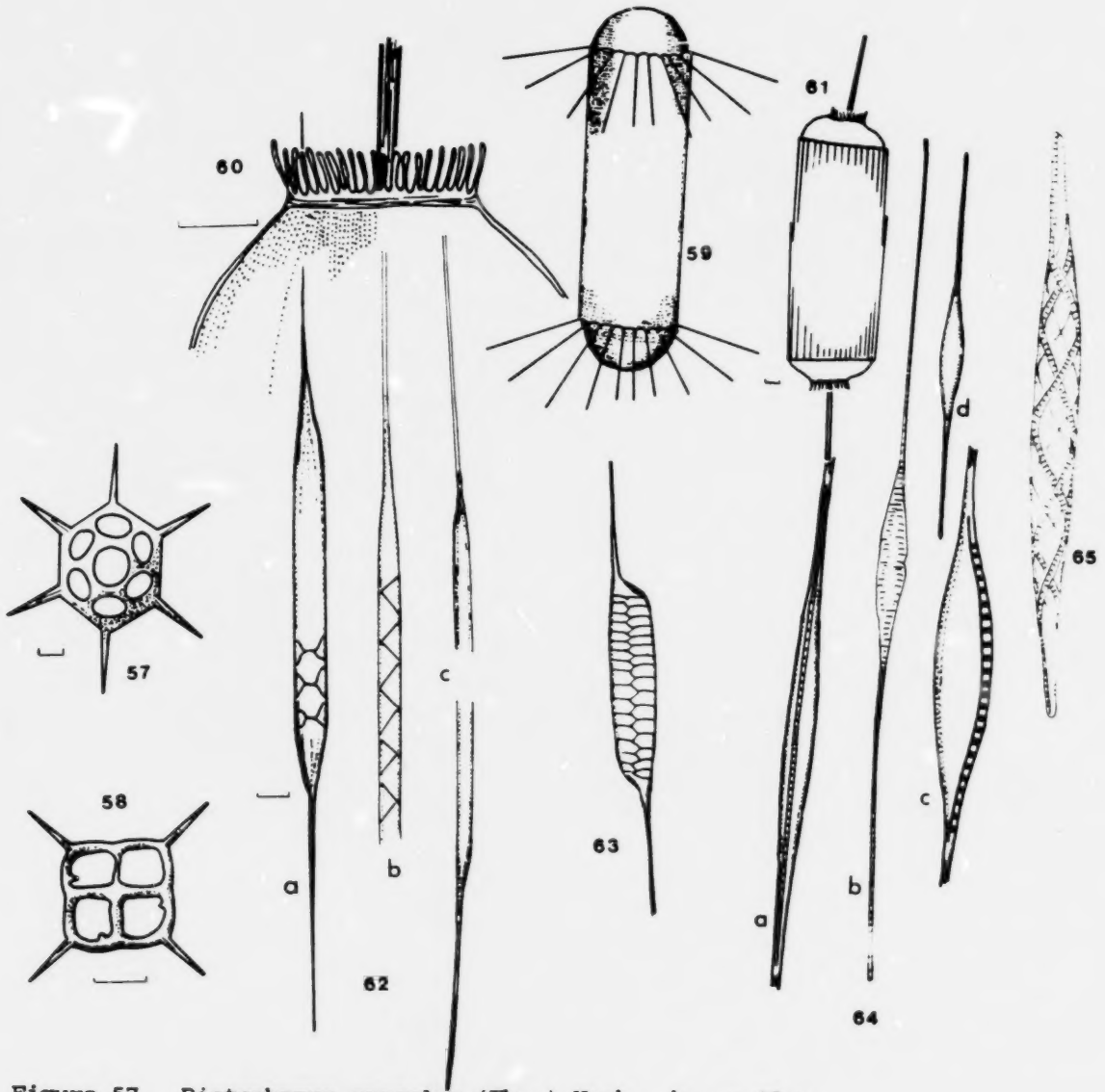

Figure 57. Distephanus speculum (Ehr.) Haek. bar = 10µ
Figure 58. Dictyocha fibula Ehr. bar = 10 µm
Figure 59. Corethron criophyllum Castracane
Figure 60. Ditylum brightwellii (West) Grun. detail of frustule end. bar = 10 µm
Figure 61. Ditylum brightwellii (West) Grun. typical cell. bar = 10 µm
Figure 62. Rhizosolenia setigera Brightw. a) typical cell. b) part of a cell end. c) typical ends of a long cell. bar = 15 µm
Figure 63. Rhizosolenia eriensis H.L. Smith x 1000
Figure 64. Nitzschia longissima (Bréb.) Ralfs. a) section of a cell with keel and puncta. b) & d) typical cells. c) detail of a cell in (a) above.
Figure 65. Cylindrotheca gracilis (Bréb.) Grunow. typical cell

Figures 60, 61, 62 & 64 after Cupp (1943). Figure 59 after Hendey (1964). Figure 63 after Hustedt (1930). Figure 65 after Bourrelly (1981).

SECTION 14

Frustules sigmoidal, or slightly sigmoidal in outline. (Many of these species require acid cleaning in order to distinguish the detail necessary for identification.)

1....Striation (after acid cleaning) intersecting i.e. running in two different directions.....2

.....Only one pattern of striation.....10

2....Striation intersecting at right angles. (Gyrosigma).....3

.....Striation intersecting at less than right angles (Pleurosigma).....6

Gyrosigma

3....Frustules with apices drawn into narrow extensions, pointing in opposition direction. Gyrosigma fasciola (Ehr.) Griff. 8 Henfr. v. Sassiola Figure 66

.....Frustules not as above.....4

4....Frustules lanceolate, tapering form the middle...Gyrosigma litorali W. Sm. Figure 67

.....Frustules linear, except at the apices.....5

5....Frustules about 15 times longer than broad. Gyrosigma balticum (Ehr.) Rabh. v. balticum Figure 69

Pleurosigma

6....Central median line.....7

.....Eccentric median line...Pleurosigma formosum W.Sm. Figure 70

7....Frustules lanceolate, tapering from the middle.....8

.....Frustules of different form.....10

8....Median line slightly angular, weakly sigmoidal Pleurosigma angulatum (Quek.) W.Sm. v. anagulatum._ Figure 71

.....Frustules about 3 times as long as broad, rounded ends. Pleurosigma strigosum v latum Cl. Figure 72

Other genera

10...Frustules with a keel on one side; the keel composed of a series of dots. Nitzschia sigma Sm. Figure 73

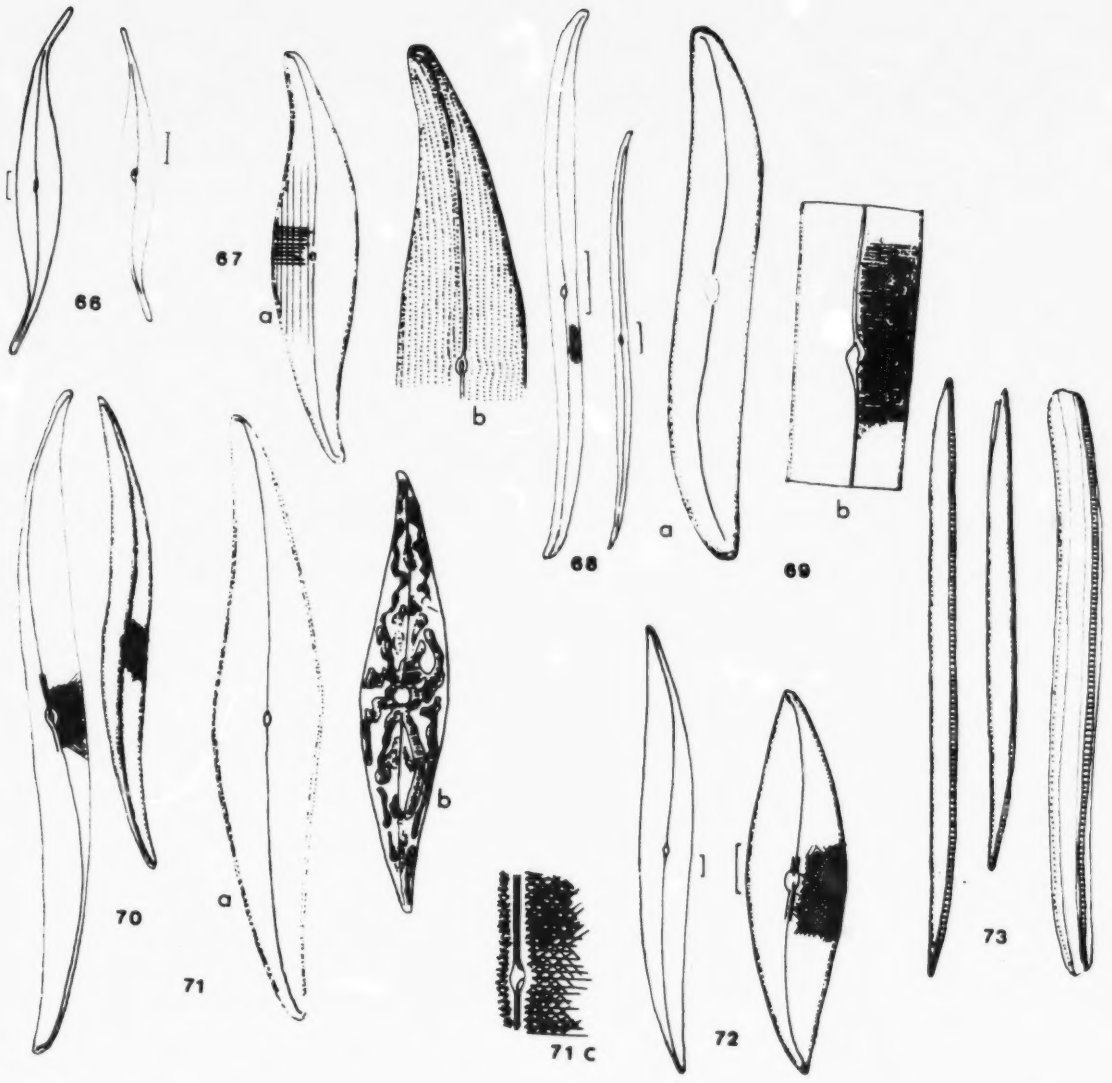

Figure 66. Gyrosigma fasciola (Ehr.) Griff & Henfr. v. fasciola. typical cells bar = 10 µm
Figure 67. Gyrosigma litorale W. Sm. a) entire frustule. b) detail
Figure 68. Gyrosigma tennuissimum W. Sm. two typical cells. bars = 10 µm
Figure 69. Gyrosigma balticum Ehr.) Rabh. v. balticum. a) typical frustule. b) section in detail
Figure 70. Pleurosigma formosum W. Sm. typical cells
Figure 71. Pleurosigma angulatum (Quek.) W. Sm. v. angulatum. a) entire frustule. b) showing the protoplast. c) showing the pattern of frustule marking.
Figure 72. Pleurosigma strigosum v. latum (W. Sm.) Cl.
Figure 73. Nitzschia sigma. Sm. typical cells

Figures 66 - 68, 70, 71b and 72 after Cleve-Euler (1968). Figure 69 after Hendey (1964). Figure 71a and c after Hustedt (1930). Figure 73 after Schmidt (1874).

SECTION 15

Outline of the frustule asymmetrical in at least one plane

1....Frustules wedge or fan-shaped.....2

.....Frustules not as above.....3

2....In girdle view, wedge-shaped with apparent septa; in valve view fan-shaped with striation. Licmophora lyngbyei (Ktz.) Grun. Figure 74

3....Frustule constricted strongly at one pole, markedly asymmetrical in valve view. Gomphonema acuminatum Ehr. Figure 75

.....Frustules not as above.....4

4....Frustule margins parallel.....5

.....Margins otherwise.....6

5....Valve lunate, small terminal nodules. 20-150 µm long, 5-6 µm wide Eunotia curvata (Ktz.) Lagerst. v. curvata. Figure 76

.....Frustules rectangular in girdle view, elongate, only slightly bent, vented margin straight or slightly concave 17-140 µm long, 5-10 µm wide. Eunotia pectinalis (O.F. Müll.) Rahb. v. pectinalis. Figure 77

6....Frustules with one margin straight, the other arcuate. Eunotia incisa W.Sm. ex Greg. v. incisa, Figure 78

.....Frustules with one margin constricted in the middle, the other margin with a keel. Nitzschia bilobata Sm. Figure 79

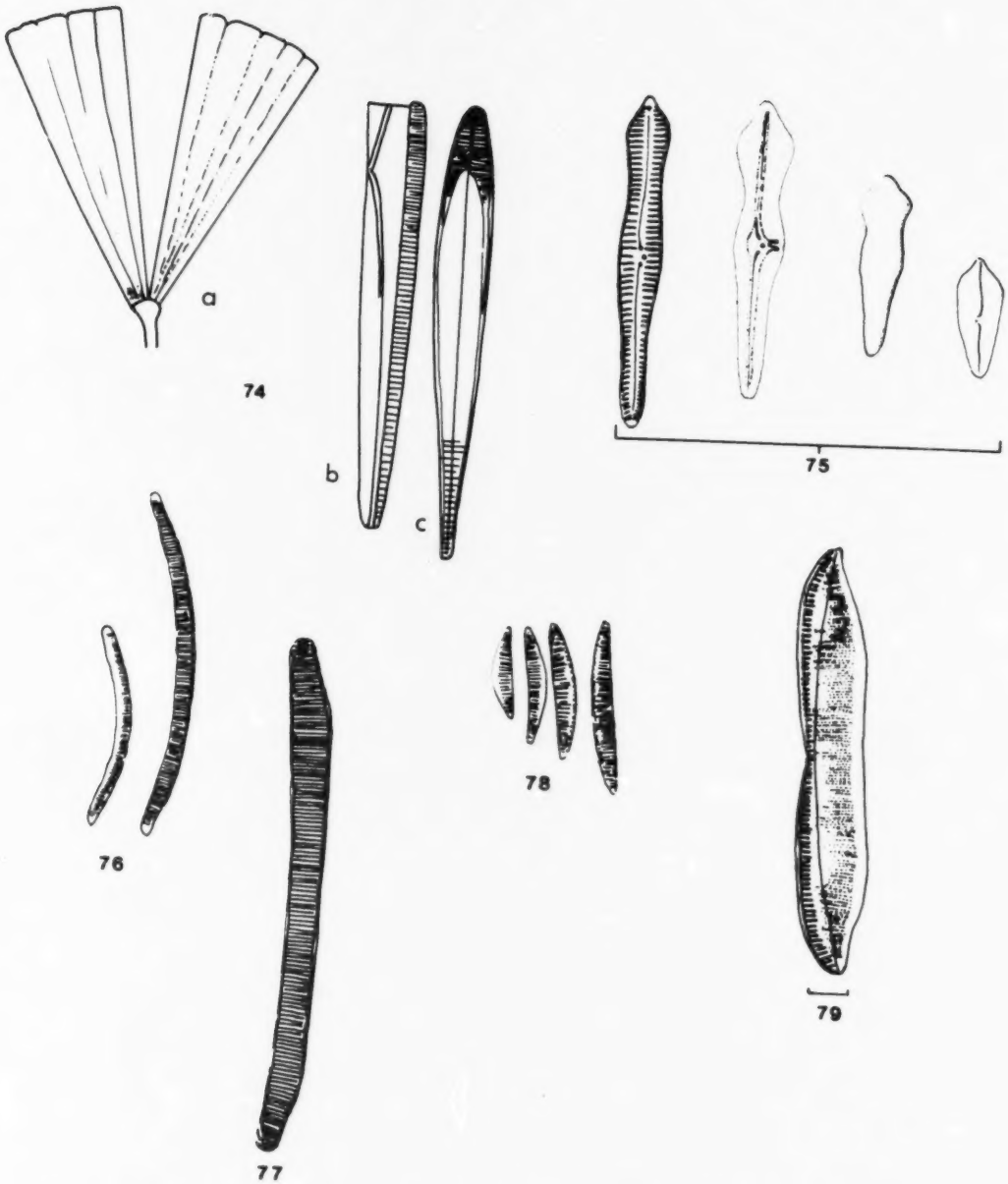

Figure 74. Licmophora lyngbyei Ktz. a) habit. b) detail, girdle view. c) valve view.
Figure 75. Gomphonema acuminatum Ehr. showing the range of valve form.
Figure 76. Eunotia curvata (Ktz.) Lagerst. v. curvata. two frustules in valve view. x 1000
Figure 77. Eunotia pectinalis (O.F. Müll?) Rabh. v. pectinalis, valve view x 1000
Figure 78. Eunotia incisa W. Sm. ex Greg. v. incisa, showing the range of valve form. x 1000
Figure 79. Nitzschia bilobata Sm. girdle view. bar = 10 µm

Figure 74 after Cleve-Euler (1968). Figures 76 - 78 after Hustedt (1985). Figure 75 after Schmidt (1874-1944). Figure 79 after Peragallo (1897 - 1908).

SECTION 16

Frustules in this section many times longer than broad, sometimes distinctly elongate or needle-like, some forms colonial.

1....A series of markings along one margin forming a keel. Nitzschia subtilis (Ktz.) Grun. Figure 80

.....Keel absent.....2

2....Frustule with a distinct-median space (pseudoraphe) the length of the cell equal to 1/3 of the frustule width, striae marginal, central area absent. Frustule slightly narrowed toward the tip, distinct jelly pore near one end. Synedra fasciculata (Ag.) Ktz. v. fasciculata. Figure 81.

.....Narrow, pseudoraphe.....3

3....Frustules with a central area devoid of ornamentation.....4

.....Pattern of sculpturing uninterrupted from end to end, frustule linear in outline, pseudoraphe narrow, distinct, ends broadly rounded. Synedra gaillonii (Bory) Ehr. v. gaillonii Figure 82

4....Frustules with a generally rounded central space, linear, gradually tapered, ends rostrate Synedra ulna (Nitz.) Ehr. v. ulna. Figure 83

.....Frustules with a rounded central area. Cells narrow, tapered, needle shaped; rostrate, rounded apices. Synedra radians Ktz. v. radians. Figure 84

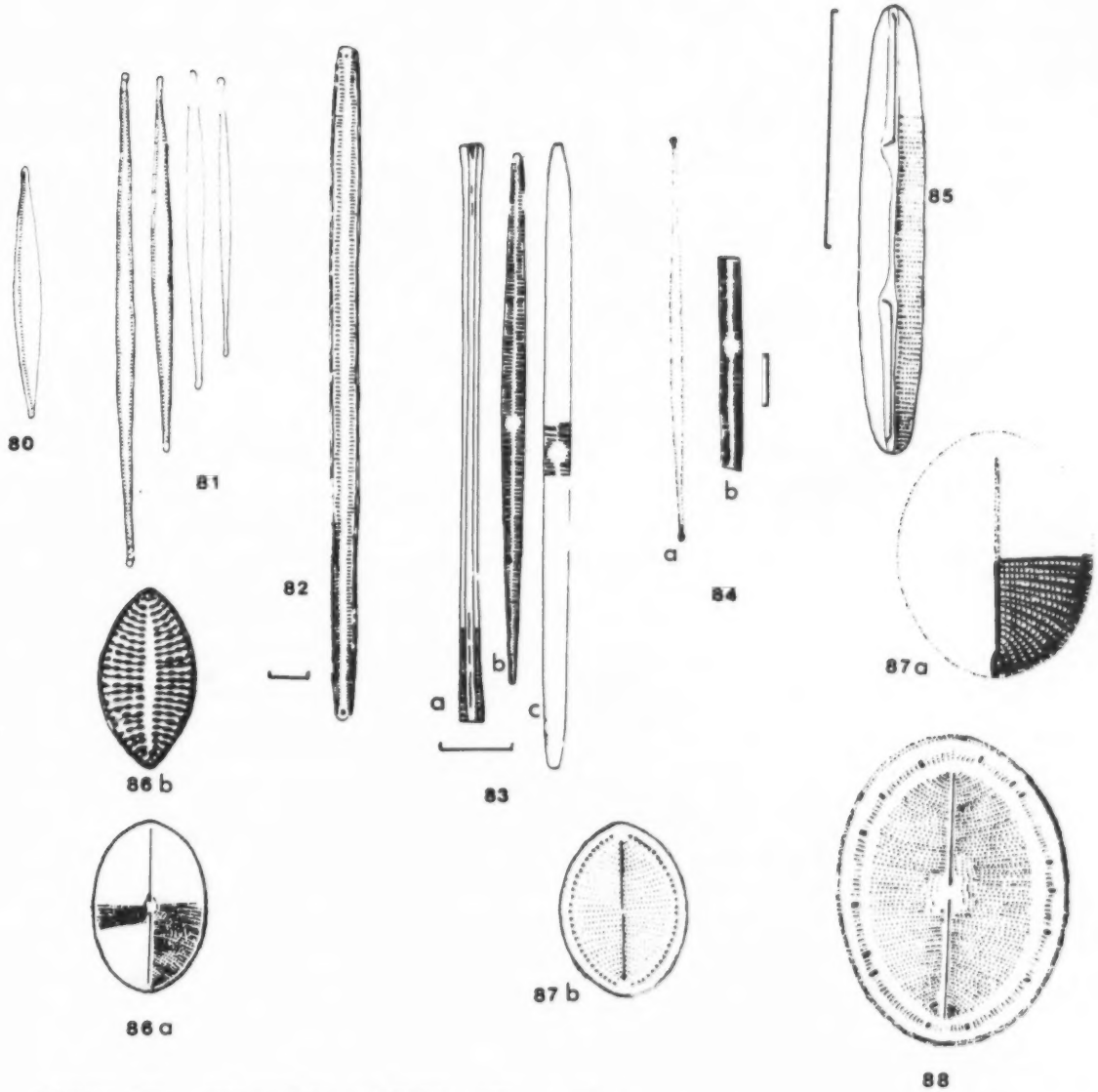

Figure 80. Nitzschia subtilis (Ktz.) Grun.
Figure 81. Synedra fasciculata (Ag.) Ktz. v fasciculata.
Figure 82. Synedra gaillonii (Bory) Ehr. v. gaillonii bar = 7.5 µm
Figure 83. Synedra ulna (Nitz.) Ehr. v. ulna. x 1000 a) girdle view. b) valve views
Figure 84. Synedra radians Ktz. v. radians Hustedt. x 1000 a) valve view. b) typical girdle views
Figure 85. Berkeleya rutilans (Trentepohl.) Grun. x 1000
Figure 86. Cocconeis distans Gregory. a) raphe, and. b) raphless valves x 1000
Figure 87. Cocconeis scutellum Ehr. a) raphless valve. b) raphe valve from different frustules. x 1000
Figure 88. Cocconeis placentula Ehr. v. placentula. raphe valve. x 1000

Figures 81, 83, 85 - 88 after Hustedt (1985). Figure 84 after Schmidt (1874-1944). Figure 80 and 82 after Peragallo (1897 - 1908).

SECTION 17

Frustules with a narrow central region, devoid of ornamentation, the length of the cell. Sometimes also with a median line (raphe)

1....Central region symmetrical.....3

.....Central region asymmetrical.....2

2....Median line with hyaline region (area without ornamentation) expanded into two lobes up to 1/3 the width of the cell. Berkeleya rutilans (Trentepohl.) Grun. Figure 85

3....Punctae coarse, easily visible.....4

.....Punctae fine.....5

4....Punctae very distant, 4 - 6 to a row Cocconeis distans Greg. Figure 86

.....Punctae not as distant, marginal ring sometimes visible, Cocconeis scutellum Ehr. Figure 87

5....Frustule with a marginal ring separated from the bulk of the valve by an inner hyaline ring (devoid of ornamentation) Cocconeis placentula Ehr. v. placentula Figure 88

SECTION 18

Frustules with a small central region expanded laterally to the margin of the valve.

1....Frustules with undulate margins. Stauroneis smithii Grun. v. smithii. Figure 89

2....Apices rostrate (rounded, expanded). Stauroneis anceps Ehr. v. anceps. Figure 90

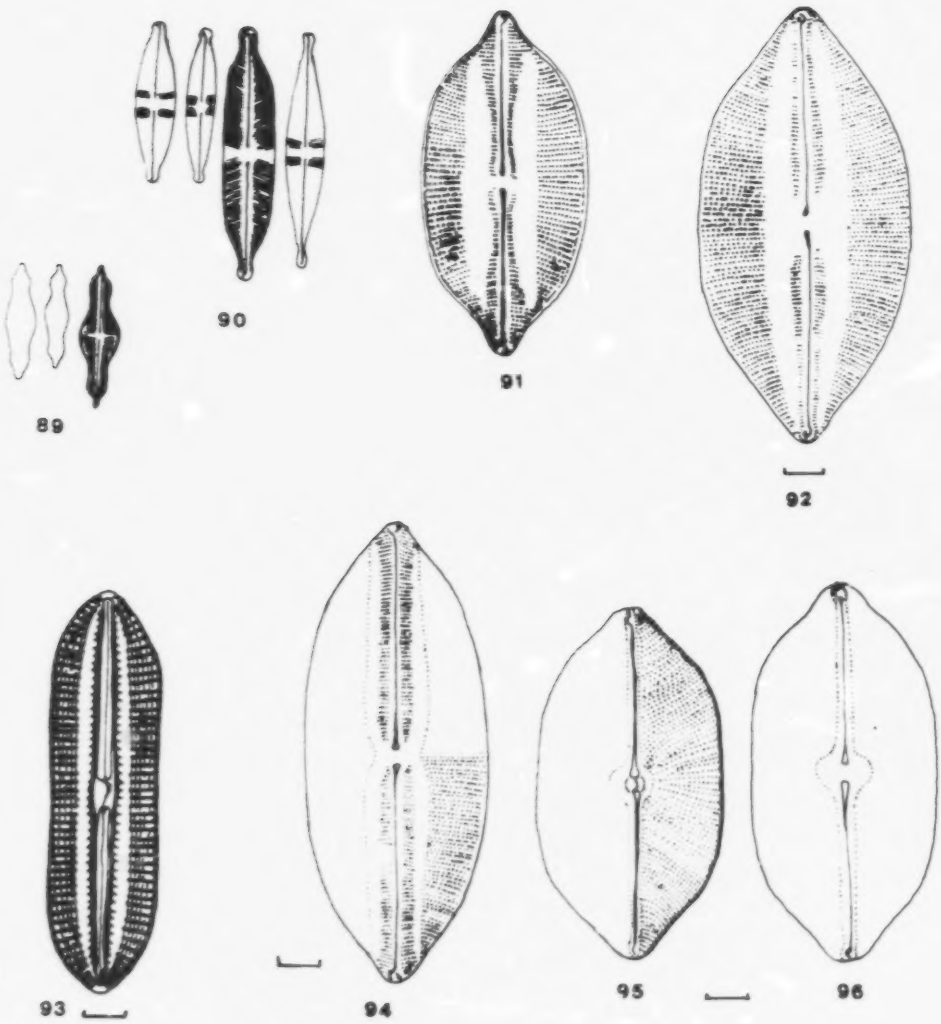

Figure 89. Stauroneis smithii Grun. v. smithii. x 1000
Figure 90. Stauroneis anceps Ehr. v. anceps. x 1000
Figure 91. Navicula irrorata Grev.
Figure 92. Navicula approximata Grev. bar = 10 µm
Figure 93. Navicula gemmata Grev. bar = 10 µm
Figure 94. Navicula lyra Ehr. v. lyra bar = 10 µm
Figure 95 and 96. Navicula granulata Bail. typical valves bar = 10 µm

Figures 92 - 94 after Peragallo (1897 - 1908). Figures 91, 95 and 96 after Schmidt (1874-1944). Figures 89 and 90 after Hustedt (1985)

SECTION 19

Frustules with a large hyaline central region (area without ornamentation) extending toward the apices, and interrupting the pattern of striae. Hyaline regions may or may not be slightly striated.

1....Frustules with protracted apices and hyaline "wings" devoid of ornamentation the length of the frustule.....2

.....Frustules not as above.....5

2....Striae beside the raphe short (3 or 4 punctae at the centre of the frustule, further out only one puncta). Hyaline "wings" not extending to the apices. Navicula irrorata Grev. Figure 91

.....Essentially as above, but hyaline "wings" extending to the apices. Navicula approximata Grev. Figure 92

.....Not as above.....3

3....Frustule margins slightly constricted in the middle. Navicula gemmata Grev. Figure 93

.....Frustule not constricted.....4

4....Hyaline "wings" narrow throughout, slightly constricted in the middle; at the apices "wings" divergent or parallel. Navicula lyra Ehr. v. lyra Figure 94

.....Not as above.....5

5....Narrow hyaline region the length of the frustule. No additional "wings". Navicula granulata Bail. Figure 95 & 96

SECTION 20

Frustules with a small central area, in which the striae are of roughly the same length and form as the neighbouring striae.

1....Frustule lanceolate, narrow lanceolate, with rostrate to capitate ends (slightly expanded). Anomoeneis vitrea (Grun.) Ross comb. nov. v. vitrea. Figure 97

.....Frustules of different form.....2

2....Frustules with coarse striae, the ends only slightly protracted: lanceolate. Raphoneis amphiceros Ehr. Figures 98 & 99

.....Frustules with the raphe surrounded by a clear central area, forming a "double" raphe the length of the cell. Frustulia vulgaris (Thwait.) De T. v. vulgaris. Figures 100 & 101.

SECTION 21

Frustules with striae in the central region shorter than those on either side.

1...Terminal striae parallel. Navicula digito-radiata (Greg.) Ralfs. Figure 102

.....Frustules otherwise.....2

.....Frustules with a narrow, linear axial region, the central region abruptly expanded to form a hyaline area

2....Frustules slightly constricted at the apices.....4

.....Apices of a different form.....3

3....Striae parallel throughout, Navicula transitans Cl. Figure 103

.....Striae weakly radiate throughout the central region, parallel convergent at the apices. Valves linear to linear - lanceolate, apices cuneate. Navicula tripunctata (O.F. Müll.) Bory v. tripunctata. Figure 104

4....Striae in the central region very short
.....Valve lanceo-elliptate, apices rostrate. Central area widened almost to the margins, terminal nodules transversely widened. Figure 105. Navicula pupula Ktz. v. pupula.
.....Valve lanceolate, striae radiate throughout. Navicula distans (W. Sm.) Figure 107

.....Striae in the central region not contracted.....5

5....Frustules strongly constricted in the middle, apices rostrate, Neidium binode (Ehr.) Hust. v. binode Figure 106

Figure 97. Anomoeneis vitrea (Grun.) Ross comb. nov. v. vitrea. a) valve view. b) girdle view. bar = 10 µm
Figure 98. Rhaphoneis amphiceros Ehr. showing the variation in valve form. x 1000
Figure 99. Rhaphoneis amphiceros v. elongata Perag. & Perag. a) valve view. b) detail of valve margin. bar = 10 µm
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Figure 101. Frustulia vulgaris (Thwait) De T. v. vulgaris. detail of valve. bar = 10 µm
Figure 102. Navicula digito-radiata (Gregory) Ralfs. bar = 16 µm
Figure 103. Navicula transitans Cl. bar = 10 µm
Figure 104. Navicula tripunctata (O.F. Müll.) Bory v. tripunctata x 1000
Figure 105. Navicula pupula Ktz. v. pupula. x 1000
Figure 106. Navicula binode (Ehr.) Hust. v. binode
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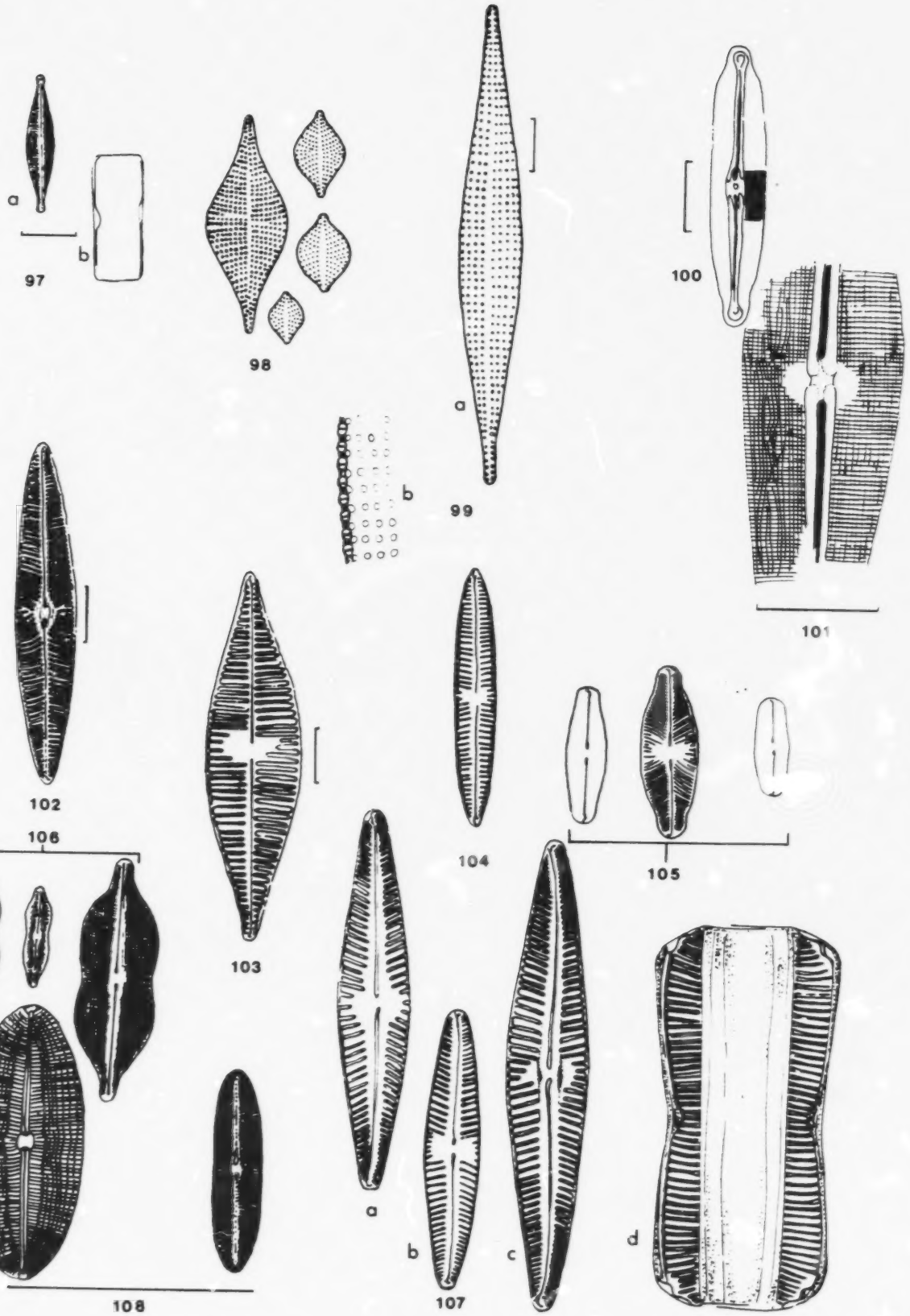
Figure 108. Navicula graeffii Grun.

Figures 97, 100, 101, 103 after Cleve-Euler (1968). Figures 98, 102 after Hustedt (1985). Figure 104 after Hustedt (1928 - 1966). Figures 99, 105 - 108 after Schmidt (1874-1944).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SECTION 22

DIVISION CHRYSOPHYTA

CLASS CHRYSOPHYCEAE

1....Lorica with smooth wall.....2

.....Lorica with marginal undulations.....4

2....Lorica sharply tapering from open end. Dinobryon sociale Ehr. Figure 109

.....Lorica more rounded, tapering gradually.....3

3....Lorica unevenly tapering from the mouth, one side distinctly expanded just above the posterior end. Dinobryon cylindricum Ehr. Figure 110

.....Lorica expanded unevenly toward the base. Dinobryon sertularia Ehr. Figure 111

4. Lorica with a at the posterior end, Dinobryon pediforme (Lemmerm.) Steinecks. Figure 112

.....Keel absent.....5

5....Lorica with an extended, tapering base. Dinobryon bavaricum Imhof. Figure 113

.....No such extension present.....6

6....Dense, diverging colonies, with cells bent as much as 90° just above the posterior end. Dinobryon divergens Imhof. Figure 114

.....Colonies compact, base forming a short stem. Walls with one or two symmetrical expansions. Dinobryon campanulostipitatum Ahlstrom. Figure 115

SECTION 23

DIVISION PYRRHOPHYTA

CLASS DINOPHYCEAE

Motile, biflagellate cells, one longitudinal flagellum wrapped around the cell in a horizontal groove.

1....Cells with apices produced into horns or spines.....2

.....Without obvious spines or horns.....5

2....Cells widest in the middle, gradually tapering to both ends. Ceratium fusus (Ehr.) Clap. & Lachmann Figure 116

.....Cells with three apical processes.....3

3....One half of the cell with two curved spines, both directed toward the posterior pole. Ceratium tripos (O.F.Müller) Nitz. Figure 117

.....Cell not as above.....4

4....Cell with three basal spines, two on the same side, one longer than the other, both pointing in the same direction. Ceratium hirundinella furcoides (Sohroed.) Figure 118

.....Cell with two short basal spines, of roughly equal length; both short. Peridinium depressum Bail. Figure 119

5....Cell with an obvious keel and collar. Dinophysis norvegica Clap. & Lachmann. Figure 120

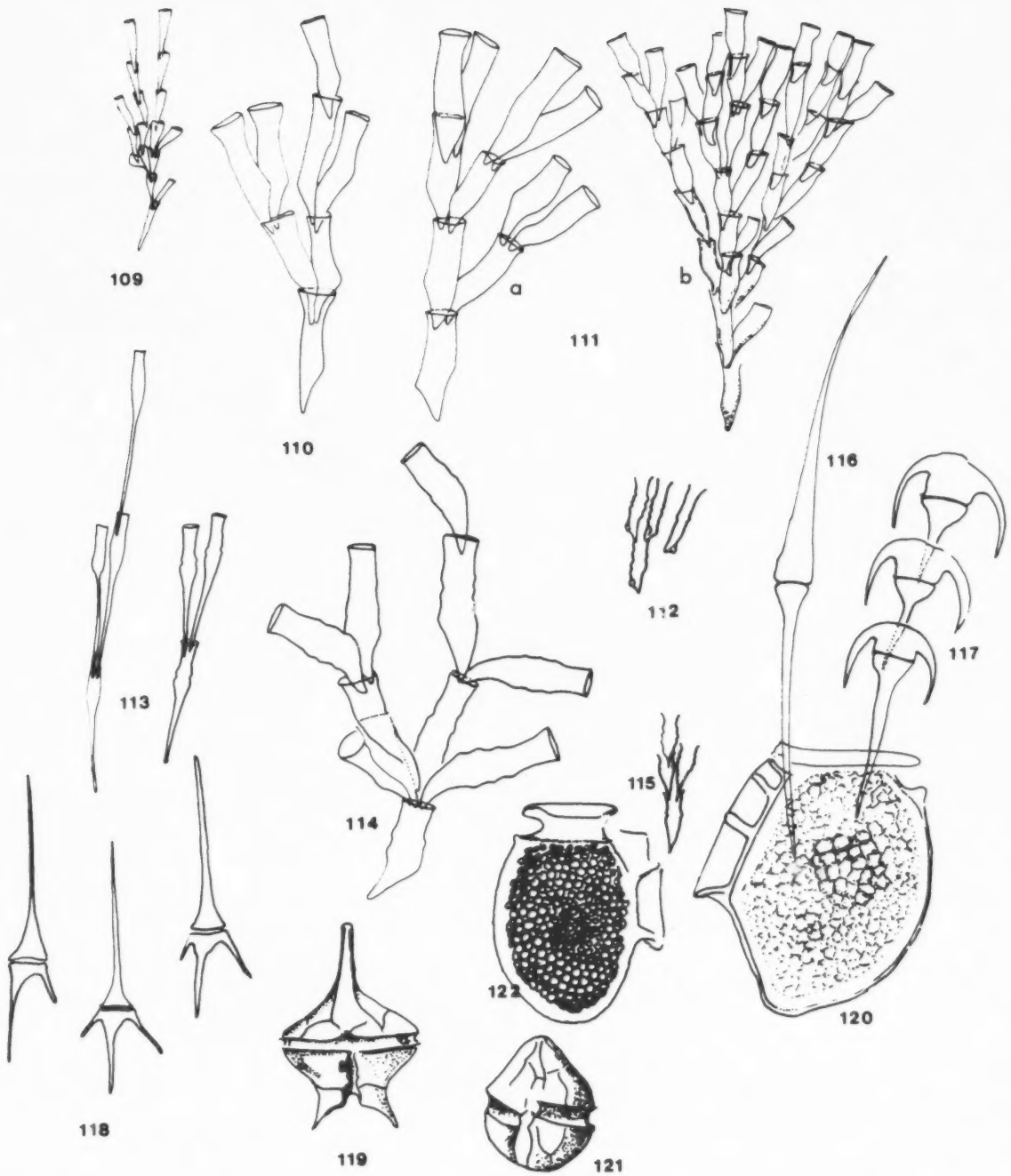
.....Cells not as above.....6

6....Cell with both transverse and vertical grooves visible, the two offset slightly at the point of intersection. Cell slightly rounded, longer than broad. Gonyaulax sp. Figure 121

.....Cell with an obvious collar, and reduced keel: Elliptical. Dinophysis ellipsoides Kofoid. Figure 122

Figure 109. Dinobryon sociale Ehr.
Figure 110. Dinobryon cylindricum Imhof.
Figure 111. Dinobryon sertularia Ehr. a) and b) habit, typical colonies
Figure 112. Dinobryon pediforme (Lemm.) Steinecks.
Figure 113. Dinobryon bavaricum Imhof. a) and b) representative loricas
Figure 114. Dinobryon divergens Imhof.
Figure 115. Dinobryon campanulostipitatum Ahlstrom
Figure 116. Ceratium fusus (Ehr.) Clap. and Lachman.
Figure 117. Ceratium tripos (O.F. Müller) Nitzsch
Figure 118. Ceratium hirundinella furcoides
Figure 119. Peridinium depressum Bail.
Figure 120. Dinophysis norvegica Clap. and Lachman
Figure 121. Gonyaulax sp. (70 - 80 µm in diameter)
Figure 122. Dinophysis ellipsoides Kofoid

Figures 109 & 118 after Hutchinson (1965); Figures 110, 111, 114 after Prescott (1951). Figure 112, 113a, 115 after Whitford and Schumacher (1969). Figures 116, 117, 119 after Wood and Lutes (1967). Figures 111b, 113b 120 & 122 original.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